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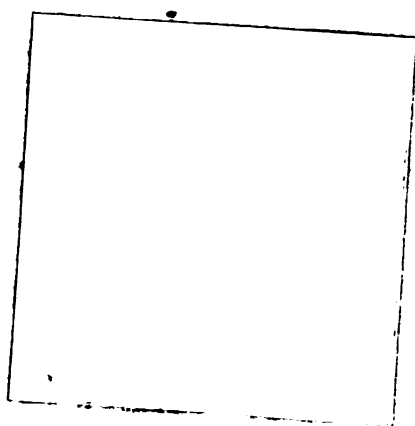
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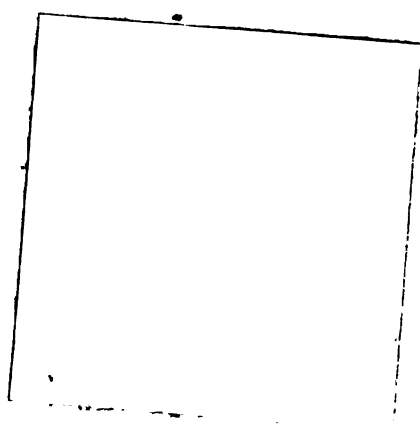
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DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

GEORGE OTIS SMITH, DIRECTOR

BULLETIN 536

THE
NOATAK-KOBUK REGION
ALASKA

BY

PHILIP S. SMITH



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PREFACE.

By ALFRED H. BROOKS.

The part of Alaska north of the Arctic Circle, including about 150,000 square miles, or 25 per cent of the total area of the Territory, is relatively little known. Its shore line, however, has been explored by various navigators. The first of these was Capt. Cook, who in 1778 skirted the western coast as far north as Icy Cape, where farther progress was blocked by the ice pack. In the succeeding half century practically the entire Arctic coast line from Bering Straits northward and eastward to the international boundary was examined in some detail by navigators of various nationalities, chiefly English, but knowledge of the inland regions was limited to that gained by short journeys up the lower courses of some of the larger rivers. Much of this information was obtained only incidentally by expeditions whose object was to reach the pole or by those sent out as relief expeditions. Thus, Sir John Franklin explored a part of the northern coast line in 1826, and the many Franklin relief expeditions contributed much toward making the shore line known. A generation later public interest was again aroused in this part of the polar sea by the ill-fated *Jeannette* expedition. This led to explorations into the Kobuk Valley and adjacent region under naval auspices (see pp. 12-14), which included a journey to Point Barrow by way of the upper Noatak and Colville River basins. About the same time the Revenue Cutter Service made some important explorations in the same field. (See pp. 13-14.) The eastern margin of the area was traversed in 1890 by J. H. Turner, of the Coast Survey, preliminary to the location of the international boundary.

The part of northern Alaska south of the Arctic Ocean-Yukon divide has been explored by prospectors, by Henry T. Allen of the United States Army, and later by several parties from the Geological Survey. The Cape Lisburne region has also been explored by the Geological Survey. In 1901 Schrader and Peters (see p. 18) carried the first instrumental survey across northern Alaska from the Yukon basin to the Arctic Ocean at the mouth of Colville River, while Mendenhall and Reaburn (see pp. 15 and 18) made a similar survey to Kotzebue Sound, at the mouth of the Kobuk. This work was far more important than any previously done, because it included

both accurate topographic surveys and systematic geologic observations. In fact, the reports based on these explorations furnished the first clue to the geography and geology of the part of Alaska north of the Yukon basin.

For eight years after these explorations the Geological Survey was too busily engaged in surveying regions of greater mineral promise to continue work in northern Alaska, but it resumed that work in 1910 and continued it in 1911. The surveys of 1911 included an exploration of the Noatak Valley, much of which was previously almost unknown. The results of these surveys are here set forth.

This bulletin, then, contains the first account of the geology and resources of Noatak River, which is among the largest streams of Alaska. The rocks of the region have been subdivided into several groups and formations, and these have been at least provisionally correlated with the cartographic units used in mapping adjacent areas. This stratigraphic subdivision is remarkably detailed, considering the very hurried character of the field investigations. Some valuable data have also been obtained on the extent of existing glaciers and of the former period of glaciation. Data were also obtained bearing on the occurrence of placer gold and other mineral deposits.

The brief outline given of the scientific exploration of northern Alaska shows that, although much has been accomplished, much remains to be done. Plans formulated for further work in this field are already in part in execution. In 1911 and 1912 A. G. Maddren carried geologic surveys from Porcupine River northward to the Arctic Ocean, in cooperation with the International Boundary Survey. It has also been planned to make a survey from the head of Alatna River across the upper Colville basin and down Chipp River to the polar sea. This plan was to have been carried out in 1912, but unfortunately the appropriation for the Alaska surveys was not made in time to permit it.

Mention should also be made of the investigations of this region by E. de K. Leffingwell, now being carried on under private auspices. Leffingwell has spent seven years in the exploration of the region tributary to the Arctic coast east of Colville River. His results will be of great value, as they should make it possible to establish correlations between the work of Maddren along the boundary and that of Schrader and others who have explored the region farther west.

When the results of all these surveys are available northern Alaska will no longer be an unknown land. It should then be possible to express its geologic features fairly definitely, at least in terms of its larger stratigraphic units. All this will have an important bearing on the larger problems relating to the geology of the North American continent.

THE NOATAK-KOBUK REGION, ALASKA.

By PHILIP S. SMITH.

INTRODUCTION.

SCOPE OF REPORT.

Investigations by the United States Geological Survey have closely followed the pioneer's search for deposits of valuable minerals in Alaska. In accordance with this practice, expeditions have visited parts of northwestern Alaska where mining has been in progress or where there was probability of mining in the future, and a series of reports has been published setting forth both the geologic and the geographic results obtained. The present paper is one of this series and aims to describe the main features of the Noatak-Kobuk region. The area included in this indefinite tract is shown on Plate I. It is not proposed, however, to describe all the region mapped, but rather to give attention only to the Kobuk and Noatak basins and the immediately contiguous territory. Therefore the Koyukuk and its tributaries, except Alatna River, will in the main be excluded, together with the Selawik River basin and Seward Peninsula. Though reference is made to these places, they are not part of the area considered in this bulletin. Reports on certain of these other areas have already been published and are available.¹

The present report treats mainly of the economic geology and the geographic features that have important control of the development of the mining industry. The statements are based on investigations made by the writer in the field seasons of 1910 and 1911, during which the Kobuk Valley was traversed from upper Reed River to its mouth, the Alatna was ascended nearly to its head, and the Noatak was descended for its entire length. In the Kobuk region the early work of W. C. Mendenhall left a record of observations that would not require restatement except for the fact that the edition of his report

¹ Moffit, F. H., The Fairhaven gold placers, Seward Peninsula, Alaska: Bull. U. S. Geol. Survey No. 247, 1905.

Collier, A. J., and others, The gold placers of parts of Seward Peninsula, Alaska, including the Nome, Council, Kougarek, Port Clarence, and Goodhope precincts: Bull. U. S. Geol. Survey No. 328, 1908.

Maddren, A. G., The Koyukuk-Chandalar gold region: Bull. U. S. Geol. Survey No. 442, 1910, p. 284.

Smith, P. S., and Eakin, H. M., A geologic reconnaissance in southeastern Seward Peninsula and the Norton Bay-Nulato region, Alaska: Bull. U. S. Geol. Survey No. 449, 1911.

has been exhausted and is therefore no longer available. In large measure, therefore, the parts dealing with the Kobuk have been based on the observations of Mendenhall, supplemented or modified by the later work.

ACKNOWLEDGMENTS.

It would be impossible to acknowledge individually the aid of all those who have furnished information for this report or who have otherwise assisted in its preparation, either in the field or in the office.

To the prospectors throughout the region thanks are due for unfailing courtesy and assistance. This was especially true in the placer camps on the Kobuk, where the services of Commissioner M. J. Moran, Michael Tuohey, Frank Knight, Asa Wilcox, and many others have added greatly to the writer's knowledge and personal comfort. On the upper part of Alatna River, Joseph Demandel and L. B. Cassel materially assisted the expedition of 1911 by transporting supplies in their poling boat and by helping in the back packing across the Alatna-Noatak portage. Assistance in the latter work was also afforded by Isaac Spinks, Roy King, and William McCarmant.

The pioneer work of W. C. Mendenhall and his party from the Geological Survey has been of incalculable aid in formulating plans and interpreting observations, and sincere appreciation of this help is expressed. Although it has been intended to credit to him the various passages in the following pages actually derived from his published reports, it has not everywhere been possible to do so consistently and his influence has been much greater than is indicated by the specific references.

To the members of the Survey who have served with the writer in the field or in the office hearty acknowledgments are due. H. M. Eakin, of the party of 1910, completed a very creditable topographic map of the region between the Koyukuk and Kobuk and did practically all the petrographic work in the office, besides supplementing the writer's geologic observations. Special credit is due C. E. Giffin, topographer, of the expedition of 1911, whose energy and resourcefulness carried along mapping rapidly without sacrificing accuracy. Deep obligations are also expressed to Messrs. E. O. Swedberg, T. A. Saling, H. M. Saling, and J. C. Doyle, temporary employees throughout the field season, who with unfailing cheerfulness and effectiveness contributed largely to the completion of the work undertaken. The microscopic examinations of the rock specimens collected by this expedition were made by J. B. Mertie, and the paleontologic determinations by T. W. Stanton, George H. Girty, and E. M. Kindle, of the Survey.

GEOGRAPHY.

HISTORY OF EXPLORATION.

EARLY EXPEDITIONS.

The earliest explorations of the area were made in the more accessible coast regions. By the close of the first quarter of the nineteenth century various naval expeditions had charted the shore line, so that subsequent surveys have added little more than details. Lieut. von Kotzebue,¹ in search for oceanic connection eastward to the Atlantic, in August, 1816, discovered the sound that bears his name. Many topographic features escaped his notice or were so crudely sketched that it remained for Capt. Beechey in 1826 to make a more accurate map. Considering the conditions under which this work was done the chart by Beechey is remarkable and has been the base from which all subsequent maps of this coast have been made. Not only were portions of the shore line surveyed, but in addition Hotham Inlet was discovered and some of the higher points inland were located, many of the present names being given by members of this expedition. A large river or narrow bay was indicated at the place where the Kobuk enters Hotham Inlet, but no mention was made of this river or of the Noatak.²

During the search for Sir John Franklin many ships visited parts of northwestern Alaska and the reports of their investigations³ afford some information about the region. Probably the most important contributions to the accurate knowledge of the region here considered were made by John Simpson, surgeon of the *Plover*. In the winter of 1849-50 he visited Hotham Inlet and vicinity, and his account of the region contains the first mention of Kobuk or, as he called it, Kowuk River.⁴ He measured the width of the main channel, traced the course for many miles by the "pines" (spruce), and learned of a village seven days' journey upstream. The first map indicating the presence of a large river in approximately the position of the Noatak was also made by Simpson. During the winters of 1852 and 1853 he lived at Point Barrow and gathered from the natives much information which he assembled and published.⁵ Although of interest, his map serves little more than to suggest the larger drainage features. On this map the Noatak is called Nunalak or Inland River, and the Kobuk is Kowuk. Only the lower part of these rivers is mapped,

¹ Kotzebue, Lieut. Otto von, Voyage of discovery into the South Sea and Bering Straits, 1815-1818.

² Beechey, Capt. F. W., Narrative of a voyage to the Pacific and Beering's Strait.

³ Katlett, Capt., Narrative of proceedings of H. M. S. *Herald* and *Plover*; Great Britain Parliamentary Papers, sessions of 1854-55, vol. 35.

⁴ Simpson, John, Journal of John Simpson, in command of a detached party to the eastern head of Hotham Inlet in May, 1850: Great Britain Parliamentary Papers, session of February 3 to July 1, 1852, vol. 50.

⁵ Simpson, John, Observations on the western Eskimo and the country they inhabit: Great Britain Parliamentary Papers, sessions of 1854-55, vol. 35, 1855.

but they are indicated, "on native authority," as extending far inland.

A good idea of the state of geographic knowledge of this part of Alaska as late as 1869 is afforded by the map prepared by Dall and published in that year. This map was compiled from all authoritative sources, including Dall's own observations while attached to the Western Union Telegraph Expedition. On this map the Koyukuk is shown as extending only 75 miles from the Yukon (measured along the stream), whereas steamboats now ascend the river for over 500 miles and the headwaters are a hundred or more miles farther. The lower parts of the Kobuk and Noatak (called the Inland) rivers are shown, but they are described¹ as "small unexplored streams. They are prolonged far into the interior to fill up the unexplored spaces on most maps." No disparagement is intended by this quotation from Dall, but it shows the lack of knowledge of most of the interior region covered by this report at the time his authoritative article on Alaska was prepared.

KOBUK BASIN.

Little additional information was acquired during the next 10 to 15 years, but in 1883 interest in the exploration of the region was renewed. In describing these later explorations it has proved desirable to separate the work on the Kobuk, Noatak, and Koyukuk and to treat each basin in a measure by itself.

Lieut. G. M. Stoney appears to have been the first white man to go any distance up the Kobuk. In 1883, with one other white man and two natives, he spent eight days going upstream as far as Squirrel River. After having spent about 15 days in the country he returned to the States. The interest aroused by his short expedition encouraged him to undertake further exploration of the river. He was successful in getting orders from the Navy Department to investigate the Kobuk and was authorized to take the schooner *Ounalaska*, of 49 tons, and a steam cutter, his party including three petty officers and eight men. After difficulties with ice he reached Hotham Inlet on July 10, 1884. On July 19, with three white men and five natives, Stoney started up the river in the steam cutter or launch towing a skin boat and dinghy. After a journey estimated at about 275 miles the party had to leave the launch and proceed in the skin boat. In this manner the party went for five days farther upstream and reached the tributary flowing from Lake Selby. It is not possible to state exactly what was accomplished on this trip, as no report of the expedition was made and the results were combined with later surveys.

¹ Dall, W. H., *Alaska and its resources*, p. 285.

During 1884 another expedition, under the leadership of Lieut. J. C. Cantwell, of the Revenue-Cutter Service, visited the Kobuk. On this trip Lieut. Cantwell and Second Asst. Engineer S. B. McLenegan, with three other white men and one native, started up the river on July 8 in a steam launch. Difficulty with the launch forced them to leave it behind and continue in a skin boat. In this way they nearly reached the mouth of Pah River where, as supplies were nearing exhaustion, they turned back on July 29 and arrived at Hotham Inlet on August 7, passing Stoney upward bound on July 31. As a result of this expedition a report in the form of a journal was prepared by Cantwell, with notes by McLenegan on the resources and natural history, including ornithology. These observations gave a fairly complete account of the country near the river. Unfortunately, however, the report¹ included no map, and delay in publication prevented its appearance until 1889, two years after the report on the succeeding year's exploration was published.

In 1885, again under orders from the Navy Department, Lieut. Stoney, with 5 officers and 12 men in the 390-ton schooner *Viking*, a stern-wheel steamboat, the *Explorer*, and a steam cutter, the *Helena*, was detailed to explore the region. The object was to establish winter quarters and to make surveys of the surrounding country. The party reached Hotham Inlet on July 9 and started up the river on the 17th. The outfit was moved by short stages to a point now called Cosmos Creek, where cabins were erected, the settlement being called Fort Cosmos. After the last of the supplies had reached this place—August 17—the party spent the next three months in preparing for the winter.

During the winter of 1885–86 seven exploring parties were sent out to reconnoiter different parts of the Kobuk and adjacent regions. These, in chronologic order, were as follows:

December 1, 1885, Stoney left for the Noatak by way of the Ambler; returning he arrived at Fort Cosmos December 18. On December 6 F. S. Nash, surgeon, left for the Yukon, but returned before completing his mission, reaching Fort Cosmos December 12. December 26 A. V. Zane, past assistant engineer, left for St. Michael by way of Pah and Koyukuk rivers; returning from St. Michael he arrived at his starting point February 25, 1886. December 29 Stoney left for a trip into the Selawik basin across the low hills south of the Kobuk, getting back January 7, 1886. February 28 Stoney went up the Kobuk, crossed to the Alatna and thence to the Colville, and returning reached Fort Cosmos April 6. March 10 Ensign M. L. Reed went to the hot springs on Reed River and returned, reaching the fort April 2.

¹ Cantwell, J. C., Report of the cruise of the revenue steamer *Corswin* in the Arctic Ocean in 1884, Washington, 1889, pp. 40–126.

April 12 Ensign (now Capt.) W. L. Howard went by way of the Ambler to the Noatak, thence to the headwaters of the Colville, down this stream to a portage to the Chipp, and thence to Point Barrow, where he took passage on a revenue cutter to the States.

As a result of these expeditions information about a large territory was obtained, but nearly 15 years elapsed before it was published, and it then appeared in a form so condensed that many facts were omitted, many discrepancies occurred between the text and map, and other inaccuracies were allowed to creep in.¹ Although it is always difficult to estimate fairly the accomplishments of an explorer it seems that considering the time spent in the region the results obtained by this expedition were not so full as they should have been. Nevertheless, the general knowledge of this part of Alaska was much increased, and an approximate idea of the topography was obtained that has been of great service in planning subsequent surveys.

In 1885 Cantwell also made another trip to the Kobuk. On this expedition he started from the mouth of the river July 2 in a steam launch, the *Pioneer*, and reached a point near the stream flowing from Lake Selby, where the launch was abandoned and the journey was continued in a skin boat. From July 12 the party traveled upstream until, on the 21st, it reached Walker Lake, or Carloogahlooktak. After making a crude survey of the lake and the upper part of the Kobuk Cantwell turned back, reaching Hotham Inlet August 22. During this trip notes were made of the ice cliffs below the Ambler, the Jade Mountains, and other facts of interest. C. H. Townsend, an assistant in the United States Fish Commission, was attached to the party and collected much information about the birds and fishes. The report² was published in 1887, thus being available two years before the report of the Cantwell expedition of 1884, which did not appear until 1889, and 13 years before the publication of Stoney's observations.

The map prepared by Cantwell was published on a scale of about 10 miles to the inch. The general geographic position of the Kobuk, or Koowak as it is called, is good, but the form of the river is unrecognizable. The topography away from the river is inadequately shown, as isolated conventionalized hachures are used. The main contribution is the recognition of a large river extending roughly along the sixty-seventh parallel from longitude 154° W. to Hotham Inlet. The text on the whole is better than the map, but its use is in large measure dependent on personal familiarity with the region and much space is taken up with details of no permanent value.

The discovery of gold in Alaska was followed by an influx of prospectors. Although many of these men doubtless ventured into the

¹ Stoney, G. M., *Naval explorations in Alaska*, Annapolis, 1900.

² Cantwell, J. C., *Report of the cruise of the revenue-marine steamer Corwin in the Arctic Ocean in the year 1885*, Washington, 1887, pp. 21-52, maps and illustrations.

unknown territory, the information they obtained has not been made available for others. A few prospectors' accounts have been published—for example, Joseph Grinnell's experiences in the Kobuk in 1898—and afford an interesting record of the early conditions.¹

The first Geological Survey expedition to the Kobuk was sent out in 1901 in charge of W. C. Mendenhall, geologist, with D. L. Reaburn, topographer, and five camp hands. The party started at Fort Hamlin on the Yukon, ascended Dall River in canoes, portaged to Kanuti River, a tributary of the Koyukuk, descended that stream and went up the Alatna for 80 miles to Helpmejack Creek, which heads in a low saddle leading to the Kobuk. This pass was reached July 30 and the portage to the Kobuk was completed by August 8. The party then descended the Kobuk, arriving at Hotham Inlet September 3.

The report on this expedition, published in 1902, gives an accurate and systematic description of the region traversed and has been the source of much material contained in the present report. The topographic map prepared by Reaburn has been of special assistance and is the base used for the Kobuk Valley in Plate I. Although some corrections and differences in interpretation have arisen in the course of fuller investigations, the broader problems were recognized and stated by Mendenhall,² whose work has been of great service to those interested in this part of Alaska. As fuller reference is made to this report farther on, a more complete review at this place is unnecessary.

In 1910 the writer, accompanied by H. M. Eakin and two camp hands, with a six-horse pack train, left the Koyukuk near the mouth of the Hogatza on June 22 and traversed the mountains between the Koyukuk and the Kobuk. The Kobuk was crossed below the mouth of Beaver River and a few days were spent surveying the region adjacent to Beaver and Reed Rivers. The party then traveled along the northern margin of the lowland of the Kobuk, reaching Shungnak July 22. A delay of several days awaiting supplies allowed investigation of the geology in the neighborhood. On August 10 the party started down the Kobuk in a skiff and reached Kotzebue, where work for the season stopped on August 20. During this trip a visit was made to the newly discovered placers of Squirrel River, in the lower part of the Kobuk basin. A result of this expedition is a topographic map, on a field scale of about 3 miles to the inch, prepared by Mr. Eakin, showing 2,000 square miles of previously unsurveyed country. Some of the observations made on this trip have already been published³ but others appear for the first time in the present report.

¹ Grinnell, Joseph, *Gold hunting in Alaska*, edited by Elizabeth Grinnell, Chicago, 1901.

² Mendenhall, W. C., *Reconnaissance from Fort Hamlin to Kotzebue Sound, Alaska*: Prof. Paper U. S. Geol. Survey No. 10, 1902, 68 pp., maps and illustrations.

³ Smith, P. S., and Eakin, H. M., *The Shungnak region, Kobuk Valley*: Bull. U. S. Geol. Survey No. 480, 1911, pp. 271-305. Smith, P. S., *The Squirrel River placers*: *Idem*, pp. 306-319.

NOATAK BASIN.

After the early discoveries noted on page 11 the Noatak was not visited until 1885, when S. B. McLenegan, of the revenue-marine steamer *Corwin*, was detailed to explore the river. He was the first and only white man who traversed any considerable length of this river and left a permanent record of his trip prior to the Survey expedition of 1911. With only one companion, a seaman named Nelson, he started up the river July 2, 1885, in a 27-foot bidarka. By hard work they reached a point that they considered the head of canoe navigation on August 1, and after a day's rest they turned back and reached the mission at Kotzebue in eight days. A report of this trip was published in 1887 and has been practically the only source of information about the river. Although the point reached by McLenegan¹ was nearly 75 miles in an air line, or about 150 miles by river, below the real head of canoe navigation and was platted about 60 miles too far east, the general mapped form of the river was excellent. He spent so much time in forcing his way upstream that he made but few observations except along the immediate route. Although regret is felt that McLenegan did not obtain more data, credit must be given him for a good piece of work as far as he went, and his oversights are perhaps attributable to the bad weather he experienced throughout most of his trip.

The expeditions of Stoney and members of his party in the winter of 1885-86, as already stated on pages 13-14, explored parts of the upper Noatak Valley and gave the only available information about this region. Details were meager, and the delay in publication of the results and the incorporation of surveys by other expeditions make it impossible to determine satisfactorily the parts actually contributed by the Stoney party. It is stated that in the summer of 1886, on "July 12, Ensign Reed and party were sent to complete the work in the Notoark [Noatak] River. They were towed about 60 miles up the stream and left to carry explorations up to the point where I had left off in December. They returned on the 22d." Further information is not given, but as no mention is made of the Noatak Canyon, and as the party spent only a short time in the field, its explorations probably did not extend as far as longitude 162°. On Stoney's map the form of the lower part of the Noatak is good, but the middle and upper parts are unrecognizable.

During the open season of 1911 the first Geological Survey party to visit the Noatak went up Alatna River in canoes, portaged across to the Noatak, and descended that stream to its mouth. In addition to the writer the party consisted of C. E. Giffin, topographer, and four camp hands. Work was commenced at the mouth of the Alatna

¹ McLenegan, S. B., Report of the cruise of the revenue-marine steamer *Corwin* in the Arctic Ocean in the year 1885, pp. 53-53 and map, 1887.

July 1 and was finished at Kotzebue August 27, during which time an area of nearly 10,000 square miles, three-fourths of which was within the Noatak basin, was surveyed geologically and topographically. Three canoes were used in order to facilitate the movement of the different units of the party. Supplies for the entire trip were brought in from Seattle, and were sent by freight down the Yukon and up the Koyukuk to the mouth of the Alatna by the regular river steamboats. From this place the supplies were carried in the canoes or back packed. Game was abundant, so that sheep, caribou, and birds formed a considerable addition to the routine camp fare. The weather was especially favorable for the work; numerous slight showers kept the streams at a good stage, but did not make traveling disagreeable nor obscure the distant landscape except in the mountainous regions. As the present report is largely based on the results of this trip, more specific description may be omitted here.

ALATNA BASIN.

The earliest survey of the upper part of the Koyukuk basin and the recognition of Alatna River was by Lieut. H. T. Allen¹ under orders from the War Department. This trip was perhaps the most remarkable of any that has been made in connection with Alaskan exploration. Starting from the south coast of Alaska, Allen with one companion, Fred W. Fickett, ascended Copper River, crossed the mountains, and descended the Tanana to its mouth. From this place the two white men, with seven natives and five dogs, started north July 28, 1885, reaching the junction of the Kanuti and the Koyukuk August 4. At this place they procured a boat and went upstream to the mouth of John River. Then turning back they descended the Koyukuk to its mouth, surveying the river as they went. This report is accompanied by a good map of the Koyukuk, on a scale of approximately 12 miles to the inch. The descriptive text, in addition to giving a narrative of the trip, has notes on the geology and meteorology and tables of distances.

Stoney's expedition to the middle part of the Alatna River valley, already referred to, afforded some general information about this part of the valley, but the details are so inexact and in places so erroneous that confidence can not be placed in his map. This is particularly unfortunate, for many parts are nearly correct, but it requires a visit to determine the fact, and therefore the map as a whole is practically of no service.

In 1899 a Survey party in charge of F. C. Schrader, with T. G. Gerdine and D. C. Witherspoon, topographers, ascended the Chandalar River from the Yukon, portaged to the Koyukuk and descended

¹ Allen, H. T., Report of an expedition to the Copper, Tanana, and Koyukuk rivers in the Territory of Alaska in the year 1885: Washington, 1887, 172 pages and maps.

that stream to its mouth. The results of this trip were the publication of a map on a scale of about 10 miles to the inch and a fully illustrated text,¹ describing the geology and geography and containing also notes on the mineral resources.

Two years later, in 1901, another Survey party, in charge of W. J. Peters, topographer, with F. C. Schrader, geologist, Gaston Philip, topographic assistant, and five camp hands, was detailed to make a trip from Bergman on the Koyukuk to the Arctic coast by way of John River. In order that the expedition should be under way as early as possible in the spring it was necessary for the men to leave Skagway in February and go to Bergman overland by dog team. While awaiting the break-up of the ice in the rivers a preliminary reconnaissance was made up Alatna River by Gaston Philip as far as the Kutuk. Unfortunately the original notes of his trip have been lost, so that, except a sketch map of his route and a general statement in the report,² no specific details of his trip are available. Although the route of the main expedition up John River and down the Colville lies outside the region directly considered in the present work, Schrader's report affords so much information on the near-by areas that many references are made to it in the following pages.

In 1901 the Mendenhall expedition to the Kobuk, already described (see p. 15), ascended the Alatna 80 miles, to the mouth of Helpmejack Creek. From the published account³ of this trip, as well as from the original notebooks, many facts have been taken to amplify the present report. The topographic map prepared by Reaburn has been used as the base for the lower part of the Alatna as far as Helpmejack Creek and for that creek and the pass to the Kobuk.

The expedition of 1911, as already stated, traversed the Alatna from its mouth to the head of canoe navigation and spent nearly a month in the basin of this river. In addition to mapping the country immediately adjacent to the river, the party made side trips on foot into the hills and obtained a general view of the surrounding country. The results of this expedition are here stated fully for the first time, though a preliminary report on the mineral resources has been recently published.⁴ As these observations are given in full on succeeding pages, further review of the work of this expedition will be omitted here.

¹ Schrader, F. C., Preliminary report on a reconnaissance along the Chandalar and Koyukuk rivers, Alaska, in 1899: Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 2, 1900, pp. 441-488.

² Schrader, F. C., A reconnaissance in northern Alaska: Prof. Paper U. S. Geol. Survey No. 20, 1904, 139 pp., maps and illustrations.

³ Mendenhall, W. C., Reconnaissance from Fort Hamlin to Kotzebue Sound, Alaska: Prof. Paper U. S. Geol. Survey No. 10, 1902, 68 pp., maps and illustrations.

⁴ Smith, P. S., The Alatna-Noatak region: Bull. U. S. Geol. Survey No. 520, pp. 315-338,

MAJOR FEATURES OF THE GEOGRAPHY.

Alaska has been divided by Hayes,¹ Brooks,² and others into several large geographic provinces, which, from south to north, have been called the Pacific Mountain system, the Central Plateau region, the Rocky Mountain system, and the Arctic Slope region. The Noatak-Kobuk region lies almost entirely within the third province—the Rocky Mountain system. Most of it is drained by Noatak and Kobuk rivers, which flow westward to Kotzebue Sound, but part of it is drained by the Alatna, a tributary of the Koyukuk, which forms a part of the Yukon drainage. Although mainly of mountainous topography, the region is so much diversified by highlands and lowland, by valleys and ridges, that in places the reason for assigning the country as a whole to the Rocky Mountain system is not apparent to one contemplating only the immediate details without regard to their larger relationship.

Schrader³ has suggested that the Rocky Mountain system has two axes, one north and the other south of the Noatak. Not enough is known of the region to the north to verify this statement. Certainly there appears to be a major axis of deformation to the south, between the Noatak and the Kobuk. As a result of this structure, the larger streams have courses either normal to the constructional trend or parallel to it. It is not proposed, however, to go into these details here further than to suggest that the general north-south trend of the Alatna Valley may originally have been normal to this axis, whereas the general trend of the Noatak and the Kobuk valleys is parallel to it. Since this mountain building took place, however, so much normal erosion and glaciation has affected the region that few or none of the constructional slopes are preserved. The general east-west trend of both the topography and the geologic formations is still one of the most notable features of the region.

As practically the entire area comprising the Kobuk, Noatak, and Alatna valleys lies north of the Arctic Circle, and as the region as a whole is a mountainous province, its climate, vegetation, and fauna are mainly those characteristic of highlands in the frigid zone. This fact is perhaps even more striking than the mountainous topography or the general east-west trend.

It is proposed in the following pages, before the geology and the mineral resources are considered, to describe the general features of the geography and to give information of a relatively nontechnical character concerning the drainage, relief, climate, flora, and fauna, and the population and settlements. As each of three river basins differs

¹ Hayes, C. W., Expedition through the Yukon district: Nat. Geog. Mag., vol. 4, 1892, pp. 117-182.

² Brooks, A. H., Geography and geology of Alaska: Prof. Paper U. S. Geol. Survey No. 46, 1906, p. 17.

³ Schrader, F. C., Prof. Paper U. S. Geol. Survey No. 20, 1904, p. 41.

from the others in many respects, and forms a rather distinct unit, they will be described separately.

DRAINAGE AND RELIEF.

KOBUK BASIN.

For purposes of description the region adjacent to the Kobuk may be divided into three more or less distinct parts which are, from the mouth eastward, the delta, the Squirrel River to Reed River province, and the headwater mountain province. It should be noted, however, that these terms have reference only to the region near the river, for the so-called headwater mountains extend practically without interruption along the north side of the river all the way to its mouth, though in some places they are distant from the river and in others are close to it. It is evident that they form the highlands in which all the tributary streams rise, and therefore had exploration been more extensive it would be more logical to divide the basin into the highlands, the valley slopes, and the valley floors.

THE DELTA.

The delta portion of the Kobuk above water extends westward from a point a short distance below Squirrel River. It is approximately 35 miles long and from 20 to 30 miles wide. In this area the main stream splits into a great number of channels, which further subdivide and reunite, forming an untraversable network of streams. Stoney¹ notes that there are 13 mouths to the river, but so far as known only two or three are much traveled. Stoney, Mendenhall, and Smith traversed the middle channel, which enters Hotham Inlet nearly opposite Nimiuk Point, 28 miles from Kotzebue. Cantwell apparently ascended the southern channel, which enters almost at the beginning of Selawik Lake and is 25 miles farther away from Kotzebue; the northern channel has not been surveyed, but natives report that it follows along the southern flanks of the hills and is nearly as deep as the other channels. The middle route is the one most used and is therefore believed to be the best. One unacquainted with the river would have considerable difficulty in finding the way, for the current is slight and is often reversed by the tide during periods of high water or strong onshore winds. Stoney reports that 2 fathoms may be carried over the bar at the entrance to the middle channel, but from the reports of other travelers it is believed that there is usually little more than half as much water.

The islands between the different distributaries are low, few being more than 5 feet above the summer stage of the river. The natives report that these flats are usually overflowed in the spring and are

¹ Stoney, G. M., *Naval explorations in Alaska*, Annapolis, 1900, p. 46.

covered with blocks of ice discharged by the river. From the scars on the trees and the accumulation of driftwood brought down during the high stages it was evident that much of the region must have been recently under water. The immediate banks of the river are the best-drained parts of the delta and usually furnish sufficient dry ground for pitching camp, but farther away the ground in summer is a wet spongy mass of vegetation, into which one sinks at least ankle deep.

Some small tributaries rising in the hills north of the delta undoubtedly enter the northern channel, but nothing is known of them, as that part of the region has not been visited. North and west the delta of the Kobuk merges into the coastal lowland that skirts the northern hills and extends beyond the Noatak. To the south and east the delta merges into the low country around Selawik Lake. The presence of a delta at the mouth of the Kobuk is notable, for it is practically the only large delta on the west coast of Alaska north of the Yukon.

SQUIRREL RIVER TO REED RIVER PROVINCE.

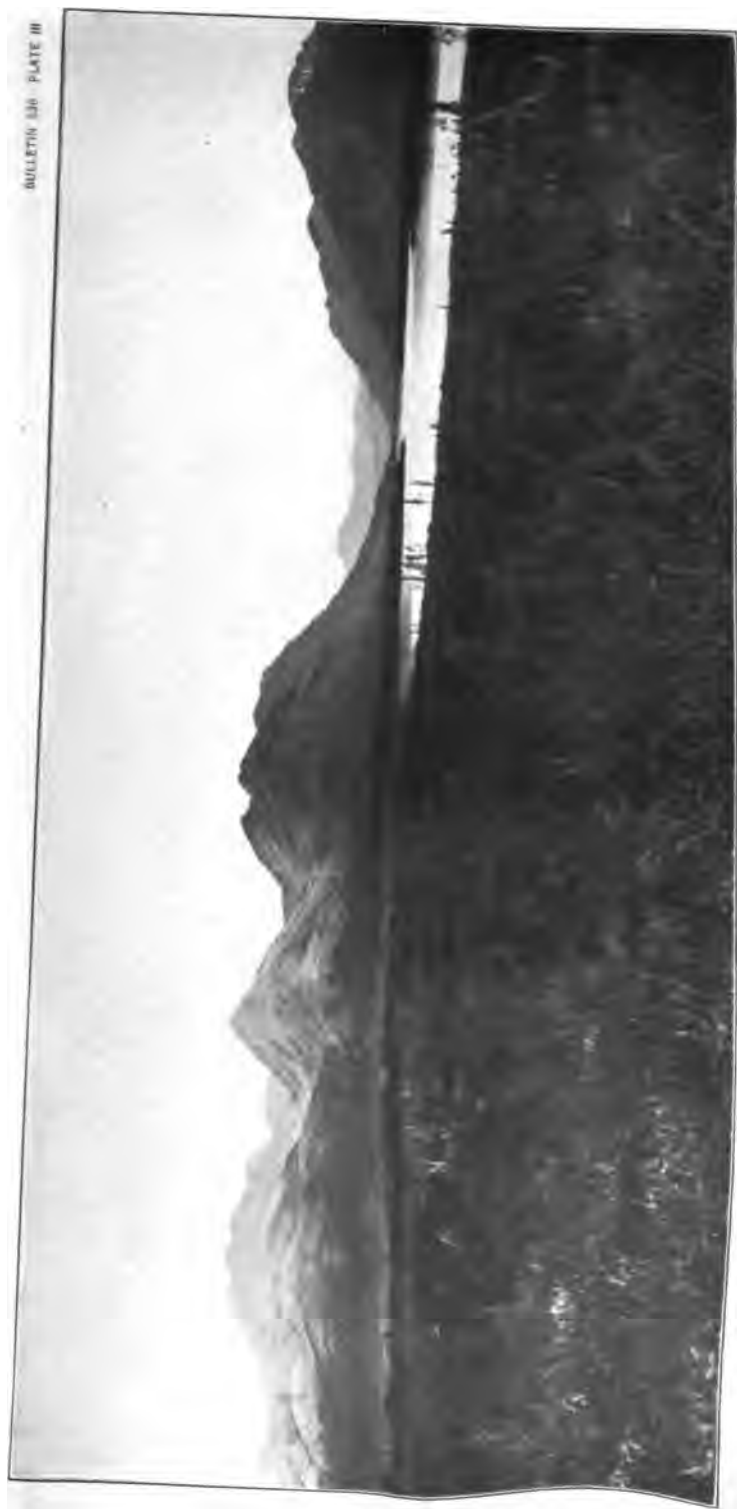
A short distance above Squirrel River the hills on the opposite sides of the river converge, and for 6 to 8 miles the valley floor is only 2 miles or so in width and rocks outcrop on both banks of the stream. Farther upstream the hills again recede and the floor averages 10 miles or more in width almost as far as the mouth of Reed River. Throughout most of this distance no rocks are exposed in the river banks, which are instead formed of sands, gravels, and silts, which here and there include ice masses 20 feet or more thick. The flood plain of the river is usually not more than 2 to 3 miles wide, and except in the part just above Ambler River the stream does not meander extensively. The river is from one-quarter to one-eighth of a mile wide and has no obstructions to navigation. The current is from 1 to 3 miles an hour, which, though not strong, makes tracking necessary. The river does not split up much into blind sloughs, so that it is easy to traverse, even by one unacquainted with the route.

Back of the flood plain there are prominent gravel terraces, which stand 100 to 200 feet above the river. Higher benches, the highest at an elevation of nearly 1,000 feet above the river, have been noted, but they are not so distinct as the lower ones. Traveling on these terraces is fairly good, as for the most part the gravels are well drained. Horses have been taken on these benches with little or no difficulty from Reed River to Shungnak, and similar country extends still farther west. Small lakes of irregular shape and size that were produced in an earlier stage of the valley development occur in places on these terraces. Here and there crescentic moraines opposite the mouths of the larger streams interrupt the nearly smooth gentle slope of the outwash plain.

North of the lowland of the Kobuk the hills rise with steep southward-facing slopes, the fronts of which are fairly well aligned, showing no long straggling spurs. This feature is particularly prominent in the stretch between Reed and Shungnak rivers, though it still appears here and there to the west. In this part the steep slopes lead to ragged peaks and ridges rising from 2,000 to 3,000 feet above the valley floor. Plate III is a characteristic view of the northern margin of the lowland, with the steep slopes and mountains in the background. The picture was taken from the gravel terrace 150 feet or so above the Kobuk, just west of Lake Selby. Except for the lake the picture is typical of the topography north of the Kobuk for about 100 miles.

One of the most peculiar features of the topography north of the Kobuk is the subordinate range of hills that lies between the Kobuk and the mountain area still farther north. This highland, which is called the Cosmos Hills, rises to an elevation of 4,000 feet and is separated from the Endicott Mountains by a lowland whose surface stands at an average elevation of less than 1,000 feet. The larger rivers rise in the Endicott Mountains, flow southward, enter the lowland, and then cut through the Cosmos Hills in steep-sided gorges, some of which are narrow floored, though others are broad. The divide between the streams in the lowland region is only about 200 feet high in places, as, for instance, between the Kogoluktuk, Shungnak, and Ambler rivers, north of Shungnak. At a distance it is almost impossible to distinguish the divides in this part of the region and travelers report that during the winter they have passed from one tributary to another without realizing the fact. With such a broad lowland region available it seems strange that the rivers have persisted across the trend of the lowland and have transected the Cosmos Hills.

In addition to these larger tributaries many streams that rise in the Cosmos Hills enter the Kobuk independently or join one of the larger branches. Some of these show peculiar features; for instance, some of the streams heading on the north side of these hills flow northward to the lowland or to a transverse stream, where they turn abruptly, cross the range, and thus enter the Kobuk. An example is Ruby Creek, which heads within 3 to 4 miles of the southern face of the Cosmos Hills but flows northward for 7 to 8 miles before joining Shungnak River; thence its waters are carried southwest about 20 miles before reaching the Kobuk. This condition prevails in spite of the fact that near its head, toward the south, there is a pass not over 400 feet above the Kobuk which has evidently been occupied by a former drainage way. Examples of this sort might be multiplied, but the one cited may serve to bring out the fact that the present



THE KOBUK VALLEY IN THE VICINITY OF LAKE SELBY.

drainage was in a large measure determined by the earlier topography. It is believed that these passes, transverse streams, and like features are best explained as due to drainage modifications induced by glaciation in the Endicott Mountains and contiguous territory in comparatively recent time.

Especially full description of the region north of the Kobuk in the eastern part of the Squirrel River-Reed River province has been given, as this region is best known. Farther west there are many large tributaries that rise in the hills to the north, but their basins are practically unexplored. Squirrel River has been visited, but only its lower part. This part of the valley is a broadly open gravel-filled lowland, in which the stream meanders in irregular fashion. Benches on the valley sides, the highest 400 feet above the stream, form prominent features, and the nearly impassable sloughs, marshes, and flats between the river and the hills are particularly notable. Many of the small tributaries of Squirrel River in their headwater parts flow in rock-cut gorges, but in their lower courses they flow in the gravel deposits of the main valley.

Passes from the Kobuk to the Noatak probably occur at the heads of many of the larger streams. A prospector with pack horses is reported to have gone to the Noatak by way of a pass north of Squirrel River, and it is probable that several low passes lead from the western part of this basin into the lower part of the Noatak Valley. At the head of Hunt River there is reported to be another pass which probably leads to Cutler River, a tributary of the Noatak. Stoney and his parties went to the Noatak by way of Ambler River; natives met by the expedition of 1911 on the Noatak reported having come by way of the Kogoluktuk and an easy pass into the Ipmluik, a stream entering the Noatak 12 miles south of the camp of August 2; prospectors report having gone to the Noatak by this route and also by way of the Mauneluk, the next large tributary of the Kobuk to the east. It is probable that no good passes to the Noatak will be found farther east until Reed River is reached.

South of the Kobuk the hills are not so high and rugged as those to the north. The same terraced country stretches from the river to the foot of the hills and the slope to the crest of the ridges is nearly as steep. The spurs do not show as well-marked alignment as on the northern side and they have a less truncated appearance. Benches that lie considerably above the river are more noticeable on the southern than on the northern hills.

No definite name has been applied to the southern range as a whole. The western part has been called the Waring Mountains, the central part the Sheklukshuk Range, and the eastern end was considered by Stoney to be part of a northeast-southwest range,

called by him the Lockwood Mountains. The latter name has here been applied to the range south of the Kobuk, and the mountains still farther south, which are entirely separate, have been called the Zane Hills. In many respects the drainage of these hills is peculiar. There are normal streams that rise on the northern face of these hills and flow northward to the Kobuk, but there are in addition some streams that rise on the southern face and, after flowing for a distance southward, turn abruptly, transect the range, and thus join the main stream. Pah River is the best-known example. As the form and relations of this river are well illustrated by the topographic map, further description may be omitted, except to point out that there is practically no divide between this stream and the Koyukuk drainage on the south and that the divide between it and Selawik River on the west is less than a thousand feet high.

Very little is known of the drainage and relief south of the Kobuk in the western part of the Squirrel River-Reed River province. From the views obtained on the Kobuk, and from the reports of Stoney and Cantwell and their maps, it seems probable that the range of hills is narrow and the streams are therefore relatively short. None of the peaks seen west of Shungnak were more than 2,000 feet high, and it is doubtful if more elevated points occur. East of Shungnak, however, some of the higher hills rise to 4,000 feet, but these are exceptional, the average elevation being probably not over 2,500 feet. Here and there a gap not occupied by a stream interrupts the continuity of the Lockwood Hills, notably at a place about 10 miles east of the mouth of Selby River, where a narrow gorge, whose bottom at the highest point is not over 500 feet above the Kobuk, and whose precipitous walls are over 1,000 feet high, cuts completely across the range.

Passes across the range south of the Kobuk can be found almost everywhere. The passes in the western part of the range lead into the Selawik basin; those in the eastern part lead into the basin of the Koyukuk. Stoney¹ reports having gone from Fort Cosmos to the Selawik by way of a pass not over 400 feet above the Kobuk. The Survey expedition of 1910 traveled with horses along the crest of the Lockwood Hills from a point west of Pah River to a point nearly south of Beaver River, so that even in its higher parts this range is not difficult to cross, and with the numerous transverse gaps a route from the Kobuk to the Koyukuk can be found that nowhere rises more than 400 to 500 feet above the Kobuk. The most traveled route between the Kobuk and the lower part of the Koyukuk is by way of the Pah. The name Pah signifies "door" and refers to the fact that this is the gateway into the Yukon basin.

¹ Stoney, G. M., *Naval explorations in Alaska*, Annapolis, 1900, p. 41.

THE HEADWATER MOUNTAIN PROVINCE.

As has already been stated, the upper part of the Kobuk Valley above Reed River is here included in the headwater mountain province. In the part of its course near the mouth of Reed River the Kobuk is one-eighth of a mile wide, but it decreases in width toward its headwaters in the high hills between the Alatna and the Noatak. Its depth also differs greatly from place to place. Near the mouth of Beaver River a sounding of over 14 feet was obtained, but natives report that above Kichaiakaka Creek the river splits up into many small streams, all of which are too shallow even for canoe navigation. Probably some of these streams rise in small glaciers, but the region has not been explored and little is known about it. Most of the valleys have forms such as are usually produced by glaciation, and there is reason to believe that in the past many if not most of the larger valleys were occupied by ice. This fact has been emphasized by Mendenhall in describing part of this region, for he states that much of the topography and stream alignments are of the confused types that result from ice work.

Several lakes form notable features in this province. The largest of these is Walker Lake, which is about 14 miles long and from 1 to 2 miles wide, and is hemmed in by rugged mountains except at its south end. Near by is Nutuvukti Lake, much smaller than Walker Lake but similarly situated. These lakes are probably of the same general origin as Selby Lake, in the more western part of the valley, already described and illustrated, and the several other mapped lakes in the neighborhood. Of an entirely different character is Norutak Lake, south of the Kobuk. It occupies a broad widely open lowland that is reported to extend uninterruptedly between the Kobuk and the tributaries of the Koyukuk.

The following description by Mendenhall¹ of the country around the head of Walker Lake furnishes a general idea of the topography of the mountain province as a whole:

The lake is bordered on both sides by precipitous mountains which rise to heights of 3,000 or 4,000 feet. Southeast of it, toward the mouth of Reed River, the country becomes broken, the hills, which are from 1,000 to 4,000 feet in height being separated by broad passes, which are often not much above the general level of the streams.

As these mountains form the divide between Kobuk, Noatak, and Alatna rivers, there will be occasion to describe some of the specific features noted in the other basins later. (See pp. 32-33, 36-38.) For the present it will suffice to point out that the peaks and ridges are lofty and rugged, with great differences in elevation, and are undergoing erosion so rapidly that they preserve in few places any evidence of an earlier topography. Bare rock crests and talus-

¹ Mendenhall, W. C., Reconnaissance from Fort Hamlin to Kotzebue Sound, Alaska: Prof. Paper U. S. Geol. Survey No. 10, 1902, p. 26.

covered lower slopes dominate and are the characteristic features of the landscape.

THE NOATAK BASIN.

The region adjacent to the Noatak may be divided into six more or less topographically distinct parts. These, from the mouth upstream, are the coastal lowland, the Igichuk Hills, the Mission lowland, the second highland, the Aniak lowland, and the headwater mountains. As was said of the Kobuk basin, it is probable that more complete knowledge of the geography would necessitate modification of these subdivisions, for they refer only to the region near the river and not to the entire basin. For instance, probably all the mountains form one main topographic unit in which the various lowlands have been carved. Inasmuch, however, as the six provinces enumerated above are the most striking features to the ordinary traveler, they will be adopted in the following description.

THE COASTAL LOWLAND.

The coastal lowland adjacent to the Noatak, as its name implies, has low relief, at no place rising more than a few hundred feet above the sea. It has the form and general characters of a coastal plain and not those of a normal delta. In fact, the delta portion of the Noatak above water, if the term delta is applied only to the part where the river splits up into distributaries, is not more than about 2 miles long. In this respect the Noatak differs in a marked manner from the Kobuk. Lakes and marshes, it is true, occur in great numbers on either side of the river for 10 miles above the mouth, but gravel benches 50 feet or more in height extend as far south as the large mapped island just above the first distributary to the west and are not periodically overflowed.

The plain is composed mainly of sands and gravels, probably of marine origin, which were deposited under water and then later uplifted and partly dissected. The slopes from the sea toward the next upstream province are rather gentle and in places no sharp line of demarcation between the two can be drawn. Near the river the upland is fairly well drained, but farther away the thawing of the surface in the summer makes an almost untraversable morass.

The main river is about a mile wide and has a gentle current. It is not much obstructed by islands or sand bars. At its mouth it is so shallow that boats must follow the channel. No soundings were made by the Survey party, but McLenegan's map shows a depth of 12 to 15 feet as far upstream as the big bend to the west near the camp of August 26. Few tributaries enter the Noatak in this part of its course and all of these are mere wet-weather streams, so that its valley is very narrow.

IGICHUK HILLS.

The topographic feature called here the Igichuk Hills, is a highland area from 5 to 15 miles wide trending in general east-west, the higher points of which rise to elevations of 1,500 to 2,000 feet. On the east these hills join those south of the Squirrel River basin of the Kobuk, which in turn are part of the general highland area called by Stoney the Baird Mountains. To the west the Igichuk Hills disappear as topographic features north of Cape Krusenstern. The most remarkable feature of this range is that the Noatak cuts through it in a narrow gorge. This lower gorge is 400 to 600 feet deep and is so recent a feature that practically no flood plains have been developed and ragged limestone points jut into the river in fantastic pinnacles. Benches along the hill slopes, the highest standing at an elevation of 1,000 feet, have been formed by water-worn gravel and sand. Above that elevation, however, the surface is mainly bare rock, affording numerous easily identifiable landmarks. Plate IV, A, gives a typical view of the Igichuk Hills from the knob 2 miles northeast of the camp of August 26, looking northwest. The Noatak, just above the point where it enters the lower gorge, may be seen to the left as a small white area. The gorge is between the low knobs in the middle ground and the higher hill at the left of the picture.

This range of hills is so narrow and low that it affords no considerable run-off, and consequently streams tributary to the Noatak heading in it are short and small. The largest are Agashashok and Igichuk rivers. The former, however, drains not only the northern face of the Igichuk Hills, but also part of the region to the north and will therefore be described later. Igichuk River enters the Noatak from the east, a short distance below the camp of August 26. Owing to the sluggishness of the current of the Noatak at this point the Igichuk has built a small delta. The stream is only 15 to 20 miles long and its basin includes not over 100 square miles.

MISSION LOWLAND.

The Mission lowland is a broad gravel-filled lowland bounded on the south by the Igichuk Hills and on the east by the highlands called by Stoney the Baird Mountains. The southwestern part of the province stretches westward uninterruptedly to the Arctic Ocean. Northeast of this broad pass there are low hills, which are higher toward the north and east and gradually converge toward the river, giving rise to the second highland province. The lowland is about 50 miles long from north to south and has an average width of about 20 miles. The greater part of the region is only 200 to 600 feet above sea level and has very low relief.

In the northern and central parts of this lowland the main river occupies a strip of the valley floor about 2 miles wide, within which

it is a network of anastomosing or braided streams, most of them shallow and difficult to follow. Although the gradient of the river is low, the volume of water is so great that the current is strong and progress upstream can be made only by tracking. The banks are low, rising only 5 to 15 feet above the water at normal stages of the river. In the southern part of this lowland, below the camp of August 22, the river is not split up but flows in a single channel for a long distance along the northern flank of the Igichuk Hills. In this part of its course the stream is deep and on the south side is bordered by gravel bluffs from 50 to 150 feet above the river. A sounding near the camp of August 23 gave a maximum depth of about 30 feet and the width of the river at that place was 900 feet, but 2 miles upstream its width was 2,200 feet.

The country back from the river is a plain covered with so many lakes of all sizes and shapes that it has been possible to represent them on the map only in conventional or diagrammatic manner. These lakes have probably been formed by diverse processes, and, although many are old, flood-plain lakes, most of them had some other origin. Here and there rounded hills one-half mile in diameter at the base rise 100 to 300 feet above the general surface of this plain. They are symmetrical in shape and, although irregularly distributed over the plain, suggest, when viewed from a distance, giant haystacks. None of these was examined at close range, but they are apparently gravel mounds similar to those near the mouth of the Colville, described and illustrated by Schrader.¹

Side streams that rise in the highlands bounding the Mission lowland flow on steep gradients until they reach the plain, where they lose velocity and meander across the flat in valleys so slightly incised and so featureless that they are not recognizable at a distance. It is uncertain where most of these streams join the Noatak, for many enter sloughs. Even those that do join near the route traveled are likely to be mistaken for sloughs. The largest tributary in this province is the Agashashok, which empties into the Noatak from the east at the extreme southeastern part of this Province. It heads far back in the Baird Mountains and probably also receives a large amount of drainage from the west face of these hills. In the lower part of its course it flows parallel to the Noatak until that river, swinging against the Igichuk Hills, cuts out the lowland and permits the tributary stream to enter. Numerous other streams rising on the western slopes of the Baird Mountains are tributary to the Noatak. None of these, however, is large, and all are unnamed. From the northern slope of the Igichuk Hills only a few short streams flow into the Noatak.

The Mulgrave Hills, which bound the lowland on the west and their continuation to the north and east, are the source of several large

¹ Schrader, F. C., Reconnaissance in northern Alaska in 1901: Prof. Paper U. S. Geol. Survey No. 20, '04, p. 94 and Pl. XVI, B.



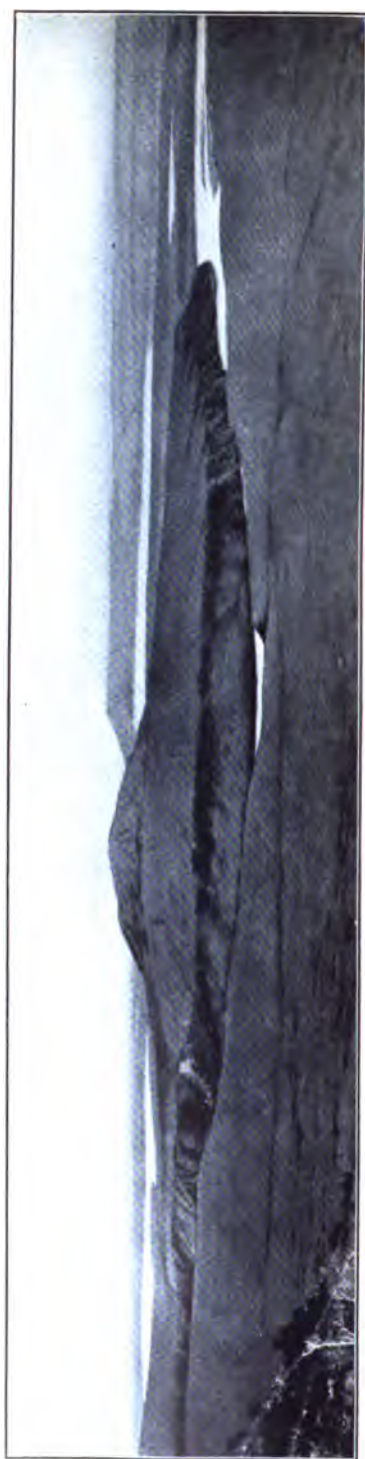
A. THE IGICHUK HILLS, NOATAK VALLEY.



B. NORTHERN PART OF MISSION LOWLAND.



A. HILLS WEST OF NIMIUKTUK RIVER.



B. TOPOGRAPHY IN THE VICINITY OF THE CANYON OF THE NOATAK.

streams. Of these the largest are Kelly River, which enters the Noatak about 8 miles in an air line above the camp of August 19, and the Kugururok, which comes into the main stream a short distance above the camp of August 18. Both these streams rise in the unexplored divide between the Noatak and the Arctic Ocean north of Point Hope, and the heads of both are reported to afford low passes into the northern drainage. The valley floors, even within the hills, appear to be very broad and steep walled, and these rivers probably extend northward for a considerable distance. Near the Noatak the streams are much split up and it is difficult to form a just idea of their volume.

Plate IV, *B*, is a view in the northern part of the lowland province, taken from a point on the south side of the river a short distance above the camp of August 19. Although the lowland is not so wide here as it is farther south, the view illustrates the braided character of the stream and the featureless plain bounded by mountains 2,000 to 3,000 feet high and 10 to 15 miles distant. At the extreme right of the view the gap in the hills marks the valley of Kelly River.

THE SECOND HIGHLAND.

The second highland province is formed by the convergence of the hills east and west of the Mission lowland. It extends from the canyon of the Noatak above the camp of August 18 to Nimiuktuk River at the camp of August 11, a distance of about 60 miles in an air line. In this part of its course the Noatak is from one-quarter to one-eighth of a mile wide. Although the river has numerous rather abrupt large bends it has no well-marked meanders and is in a relatively youthful stage. Here and there, as, for instance, 5 or 10 miles below the camp of August 11, it splits up into a number of braided streams, but through most of the province it flows in a single channel. Gravel terraces that stand 50 to 100 feet above the stream form prominent features, and higher terraces, not so noticeable, also occur. The Noatak has eroded a rather narrow steep-sided trench in these gravel deposits. Bedrock outcrops at many places on both sides of the valley, but although in some such places the current is swift there are no dangerous falls or rapids.

The hills that flank the stream rise with steep slopes to elevations of 2,000 to 3,000 feet above the river and as a rule have a rather subdued topography. Plate V, *A*, a view toward the west taken from the triangulation station near the camp of August 11, gives a general idea of the eastern part of the second highland area, which is fairly typical of the province as a whole. Most of the lakes in the foreground of this picture lie 50 to 150 feet above the river and are not on the present flood plain.

Perhaps the most striking feature of this province is the canyon that practically marks the beginning of this part of the valley. Plate

V, B, a view taken from the low hills about 2 miles south of the camp of August 14, shows the general topography of the canyon region. The Noatak, flowing from right to left in the picture, turns abruptly from the broadly open lowland north of the camp of August 14 and swings south and west through the narrow rock-walled gorge in the middle ground. One large lake and numerous smaller ones occupy the old more direct valley north of the canyon. Other views shown in this report (see Pl. XI, p. 70) give glimpses within the canyon. The walls rise precipitously 600 to 800 feet above the river and afford scarcely foothold on either side. The water rushes so swiftly through the canyon that a transverse wave reaching halfway across the river is set up as the stream impinges on the bluffs, first on one side and then on the other. In this constricted part of the river the water is deep. During periods of heavy rain the stream above the canyon rises rapidly but falls as quickly. McLenegan¹ notes that a short distance upstream the water surface fell 8 feet in a single day and states that this rapid fluctuation was one of the most noteworthy features. There will be occasion later (see pp. 93-94) to describe in more detail certain of the features in the neighborhood of the canyon which throw light upon its origin and also to describe the rocks exposed in the walls (pp. 70, 110).

Numerous side streams heading far back in the mountains to the north enter the Noatak above the canyon. It was not possible to determine definitely the position of the divide, but it appeared to be nearer the river to the south than to the north. The largest of the tributaries is the Nimiuktuk, or, as it is sometimes called, Indian River. For more than 5 miles above its mouth this stream is split up into a network of channels, which are separated from one another by low sandy islands. The western wall of the valley is marked by prominent hills, but the eastern part for at least 10 miles above the mouth of the river is a low rolling country not more than 400 to 600 feet above the stream. The depth of the valley floor below the present flood plain, however, is not very great, as outcrops of bedrock appear on both sides of the river for a mile or two above the mouth of the stream.

ANIUK LOWLAND.

East of the camp of August 11 the hills forming the second highland area recede from the river, and the last of the lowlands, here called the Aniuk lowland, commences. This is a gravel-filled depression about 75 miles long and 10 to 30 miles wide. In this part of its course the river is from one-eighth to one-sixteenth of a mile in width. There are many large angular bends in the general course

¹ McLenegan, S. B., Exploration of the Noatak River, Alaska: Report of the cruise of the revenue-marine steamer *Corwin* in the Arctic Ocean in the year 1885, p. 72, 1887.

of the stream as well as numerous much smaller meanders. The average width of the meanders is 1 to 2 miles, whereas the larger bends measured in the same way have in places a width of as much as 10 miles. The current has an average velocity of 2 to 3 miles an hour. On the whole the stream offers no serious obstacles to navigation by small boats except during periods of very low water, when the numerous boulders in the river bed cause dangerous rapids.

Plate VI, A, a view toward the south and east taken near the camp of August 7, shows a typical part of the lowland. The most prominent features in this picture are the broad, nearly level upland and the meandering river. The river has incised its bed below the general level of the upland and is more or less hemmed in between steeply sloping gravel walls that rise to heights ranging from 50 to 200 feet. Flood plains alternate with cut banks and some abandoned courses of the river are preserved as lakes. Many of the lakes seen in the view, however, lie on gravel benches 50 feet or more above the river and have had a more complex history. The upland, as is evident from the view, is an almost featureless plain, except where low rocky hills, like those shown in the center of the picture, here and there rise above the gravels. Although the upland slopes downward from the hills that bound the lowland on the north and south as well as downward along the course of the stream, it gives a general impression of being essentially flat.

Numerous small streams rise in the low country near the Noatak. The larger streams, however, rise in the distant mountains and flow across the lowland in rather narrow trenches. The largest tributary from the south, Cutler River, joins the Noatak near the middle of this basin. The Cutler was called by Lieut. Stoney the Caribou, but this name was not published until after the other had been adopted. It carries nearly one-half the volume carried by the main river above that point and drains a large region between the Noatak and Kobuk. A large tributary, the Aniuk, enters the Noatak from the north. This stream heads in the distant rugged hills that limit the lowland to the north and probably receives most of the southward drainage from those hills. Many of the tributary valleys of the Aniuk show broadly open U-shaped cross sections in the mountains and were probably once occupied by glaciers. A broad, low pass leads from the Noatak by way of the lowland into the Colville basin, which drains into the Arctic Ocean east of Point Barrow. This pass was probably traversed by Howard, of the Stoney expedition, on his trip to the Arctic Ocean. (See p. 14.) The farthest point reached by McLenegan was about 10 miles east of the mouth of the Aniuk. Aniuk River was particularly notable because of the large amount of clear water it added to the Noatak.

THE HEADWATER MOUNTAINS

The mountainous headwater province, which extends roughly for about 75 miles east and west, is formed of the mountains that stand at the headwaters of Kobuk and Alatna rivers. (See pp. 25-26.) The floor of the main valley gradually narrows from a lowland 2 miles wide, in which the river meanders in a slightly incised trench, toward the headwaters, where it is entirely occupied by the stream. Gravel deposits here and there, the highest about 1,000 feet above the river, cover the steep rock scarps that are elsewhere bare and prominent. The rocky walls rise abruptly from the valley floor and have the truncated appearance usually produced by glaciation.

In the higher hills there are small glaciers, probably the remnants of larger ones. None of those seen was more than a mile or two long and none of them extended below an elevation of 5,000 feet. In the parts of the range that were not explored even larger glaciers may be found. None of the side streams, however, showed marked turbidity, such as is exhibited by streams that receive a large part of their water from glaciers.

Many valleys heading in the divide between the Kobuk and Noatak are reported to extend long distances and to afford passes by glaciated cols from one basin to the other. Plate VI, *B*, a view up Ipmiulik River, which joins the Noatak a short distance above the camp of August 1, shows a typical side valley and the general features of the highland province. The steep slopes, the bare ragged crest lines, and the broad main valley floor, with benches near the hills, are all represented. Natives report that the Ipmiulik Valley affords an easy route into the Kogoluktuk Valley of the Kobuk basin.

In the headwater mountain region there are passes into the Alatna by way of the route used by the Survey and also by way of Lucky Six Creek and Gull Pass. The pass used by the expedition of 1911 is about 1,000 feet above the Noatak and $8\frac{1}{2}$ miles in an air line from that stream; the total distance from the head of canoe navigation on the Noatak to boating water on the Alatna is about $11\frac{1}{2}$ miles, so that this route is especially good for a canoe portage. Gull Pass is about 1,000 feet higher, is much longer, and is far more difficult. It was not surveyed, but the general topography of this route was seen from both the east and the west.

Opposite the mouth of Lucky Six Creek there is also a pass into Reed River, of the Kobuk drainage, and another pass to the same stream by way of the southern fork of the Noatak is reported. Both of these are steep and difficult, but prospectors say horses can be taken over them. A pass into Colville drainage, at the head of one of the branches of Midas Creek, was also examined. The divide is about 8 miles distant from and 2,000 feet above the camp of August 2. This route is feasible for a canoe portage, and the distance between



A. ANIUK LOWLAND FROM CAMP OF AUGUST 7.



B. NOATAK AND IPMILUIK VALLEYS.



A. UPPER PART OF ALATNA RIVER VALLEY



B. PEAKS AND GLACIERS IN CENTRAL PART OF ALATNA RIVER BASIN.

water deep enough to float canoes on the two streams is about 13 miles. This is possibly the Riley Pass traversed by Stoney on his first trip to the Colville, but his map and descriptions do not make this clear.

ALATNA RIVER BASIN.

KOTUKUK RIVER TO HELPMESACK CREEK.

The Alatna River valley has a general northwest to southeast trend. It is about 140 miles in length and is rather narrow, as the side-stream valleys are short. The basin comprises two rather distinct topographic provinces. The southern one, carved in relatively weak rocks, has subdued topographic features; the other, carved in resistant rocks, is characterized by rugged mountains.

In the southern province the valley floor is a wide gravel-filled lowland in which the stream is incised but slightly and flows in sinuous meanders that try the patience of the traveler upstream. From this widely open, partly filled valley floor gentle slopes lead to the surrounding upland, which in few places rises more than 2,000 feet above the river. In this part of its course, although the stream is too swift to allow rapid progress to be made against it by rowing, its gradient is less than 5 feet to the mile. Here and there rocks outcrop on the two sides of the river, but the ledges form no obstruction to boats. Shallow-draft river steamboats have ascended this river as far as Helpmesack Creek, but only during periods of exceptionally high water. In 1911 a small river steamboat was able to get only about 40 miles before it was stopped by shallow water, although that season was not particularly unfavorable.

The largest tributary of the Alatna in this part of its basin is Siruk Creek, which enters from the west. This stream drains the broadly open lowland that probably extends from the Alatna to the Hogatza and thence by way of the Norutak Lake valley to the Kobuk. This lowland is reported to be the main winter trail from the lower Alatna Valley to the Kobuk. Other smaller streams also are received by the main river, but few of them are more than 5 to 10 miles long and in their lower courses are seldom distinguishable from sloughs of the Alatna.

HELPMESACK CREEK TO HEAD.

Main stream.—The second topographic province extends from near Helpmesack Creek northward as far as the region was explored. In this province the river occupies a floor ranging in width from 1½ miles in the southern part to only a few feet in the headward portion, the maximum width of the stream itself being less than one-eighth mile. As far as Nahtuk Creek the river runs in a very sinuous course in a rather straight valley. Distances measured between a series of points along the course of stream in this stretch are at least three

times as great as the distances in a straight line between the two end points of the series. Above Nahtuk Creek the course of the river becomes straighter, the current swifter, and the water shallower.

From Helpmejack Creek nearly to Twin Mountain Creek the floor of the valley has gravel deposits, which form marked terraces where the river has cut its bed a hundred feet or more into them. In this part bedrock outcrops here and there but forms no serious obstruction to small boats. Good gravelly and sandy footing may usually be found in normal stages of the river near the edge of the water. The bed and shore of the river from Twin Mountain Creek to the Nahtuk is formed of quicksand which makes traveling on shore extremely difficult. Fortunately, as a result of this condition, the river has a flatter gradient and consequently a slower current, so that fair progress upstream may be made by rowing or with a favorable wind by sailing. Above Nahtuk Creek firm sand and gravel, rather coarser on the whole than the material farther downstream, furnishes good traveling near the river. Still farther upstream the river splits into numerous small streams, some of which are too small to float even a light canoe. Between these places, however, there is but a single stream furnishing ample water.

Above the mouth of the Unakserak the volume of the Alatna is so small that it may be crossed almost anywhere on the riffles without going more than thigh deep. The slope increases so much that in the 15 miles between the camps of July 20 and July 23 the fall is 700 feet, or an average of nearly 50 feet to the mile. In this part the river flows in an almost uninterrupted succession of riffles. The river, now diminished to a stream only a few feet in width, makes many abrupt bends, abutting against rocky outcrops on either side of the floor. Gravel terraces and rock-cut benches here and there rise above the stream. On the whole the valley floor has a nearly straight trend and is much wider than the stream channel.

A general view of the upper part of the Alatna Valley, looking northwest from the camp of July 23, is given in Plate VII, A, which shows Alatna River to the right, the low gravel terrace into which the stream is cutting, the valley floor—which is very wide in proportion to the size of the stream—the characteristic slope of the valley walls, and the rather straight and parallel direction of the junction between the walls and the valley floor.

Side streams.—The side streams tributary to the Alatna are all relatively short and have no considerable discharge. Practically none of these streams was explored to its headwaters, so that their length can only be inferred by their relation to known basins and by reports of prospectors.

Iniakuk River, with its tributary Malemute Creek, is the most southern of the streams entering the Alatna from the east. It is in

a measure parallel with the Alatna, but its eastern tributaries head in the range west of John River. It is reported that relatively easy portages lead by way of these tributaries to Malemute and Sixtymile rivers of the John River basin. There is also a low pass by way of one of the western tributaries to Alatna River above Lake Takahula. There will be occasion to refer again to this pass, which is picturesquely known to the natives as Akabloouk, or "daylight through the hills," in describing the glacial features of the region. On its western branch there is a lake several miles long.

Above the Iniakuk only a few small streams enter the Alatna until the Nahtuk is reached. This also comes in from the east, and its eastern tributaries are reported to head in the same hills as the western branches of the Iniakuk. Between the two there is reported to be an easy pass. About 4 miles above the Nahtuk is the Pingaluk, a small stream draining a triangular area between the Nahtuk and the next upstream creek, the Kutuk.

The Kutuk is said to be longer than either the Nahtuk or the Pingaluk. It is the river that, according to the text, Stoney ascended on his trip to Chandler Lake. According to his map, however, the Unakserak, which is the next stream north, is represented as the one he followed. Owing to this discrepancy, the fact that he traveled 35 miles to the head of the Kutuk does not definitely demonstrate the geography. Natives report that the Kutuk heads against Colville drainage, but it is believed that the portage by this route is too long to be practicable for transporting boats from one stream to the other.

From the west, a short distance below the mouth of the Kutuk, a stream heading in glaciers was explored. Although of small size, this stream heads in the highest hills of the region, from which probably the Kobuk and Noatak rivers also receive some drainage. A pass was reported to lead by way of this valley into the Kobuk and Noatak valleys. A thorough search showed that this report, like much other hearsay testimony, was untrue. Although it is probable, as has already been pointed out, that the Noatak and Kobuk lie on the other side, this divide is so nearly unscalable that almost any other route would be preferable. Plate VII, *B*, shows the head portion of this valley, and indicates not only the unfeasible character of this route but also the general type of relief.

From the west several other unnamed streams enter the Alatna. None of these require special mention here, as their general features are indicated on the map (Pl. I). Gull Creek, which joins the Alatna a short distance above the camp of July 20, however, is important, as it is reported to afford the first feasible portage into the Noatak. The pass at the head of one of the branches leads into Lucky Six Creek, of the Noatak. This route is a rather difficult one, and is not so well

The tops of the lower ridges are largely made up of the materials disintegrated through frost action, and this rubble affords good footing, so that the best traveling is along the crests. The higher ridges, however, are so interrupted by high peaks and low sags that progress is impossible and one must resort to the lower slopes, where a more level course may be selected.

CLIMATE.

TEMPERATURE.

Instrumental records of the climatic elements of the Noatak-Kobuk region, such as temperature and precipitation, cover only a short period. The only station maintained by the Weather Bureau is at Allakaket, on the Koyukuk at the mouth of Alatna River, and observations there have been carried on only since 1908.

From the Allakaket station the following records of temperature have been furnished by the Weather Bureau:

Mean temperatures at Allakaket.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	For period.
	<i>° F.</i>	<i>° F.</i>	<i>° F.</i>	<i>° F.</i>	<i>° F.</i>	<i>° F.</i>	<i>° F.</i>	<i>° F.</i>	<i>° F.</i>	<i>° F.</i>	<i>° F.</i>	<i>° F.</i>	<i>° F.</i>
1908.....	-20.4	-4.3	-5.9	16.5	42.9	56.5	57.7	51.4	.....	10.6	-6.6	-6.7	17.4
1909.....	-38.1	-23.0	-5.6	11.7	40.6	55.6	59.7	50.4	35.0	11.0	-19.0	-21.2	13.3
1910.....	-24.4	-22.3	-6.8	10.0	38.2	54.0	55.6	50.6	40.4	15.6	-8.2	-23.5	14.9
1911.....	-31.3	-1.4	-9.6	11.2	40.7	59.5	60.8	51.8	43.7	29.6	-12.1	-19.2	18.6
Average.....	-28.5	-12.7	-6.9	12.3	40.6	56.4	58.4	51.0	39.7	16.7	-11.5	-17.6	16.5

In the above table the column at the right headed "For period" has been computed by totaling the records given and dividing by the number of months during which observations were made; thus, for 1908 the mean temperature for the period is the total of the mean temperatures given divided by 11, as no record was available for September. For the column of averages at the bottom of the table a similar method has been followed for the different months. To determine the average for the period, however, the horizontal column of averages has been used and not the vertical column of "For period." Although the incompleteness of the record impairs the accuracy of the result, the average mean temperature of the different months and of the different years affords a clear idea of the general temperature conditions at Allakaket.

During the winter of 1885-86 Stoney made a series of observations at Fort Cosmos, on the Kobuk, a short distance north and about 120 miles west of Allakaket, and it is interesting to note that the average mean temperature for the 12 months he was at this post was 15.5°, which is remarkably close to that obtained at the mouth of the Alatna. It seems certain, therefore, that these observations indicate closely

the average temperature conditions for places about 500 feet above the sea in this part of Alaska in latitude 67°. In applying these data to the whole Noatak-Kobuk region, however, it should be pointed out that they are probably too high. In the first place, the observations were made at an elevation of about 500 feet, whereas much of the region is above this elevation, and consequently the average temperature is several degrees lower. In the second place, the region is a degree or more north of the observation station and is therefore probably colder.

An important feature of the climate is the distribution of low temperatures throughout the year, and the following table of minimum temperatures recorded at Allakaket during 1909 and 1910 and furnished by the Weather Bureau is significant. It is evident from this table that freezing temperatures may be expected any month throughout the year.

Minimum temperatures at Allakaket, 1909-10.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1909.....	* F. -64	* F. -57	* F. -41	* F. -26	* F. 15	* F. 34	* F. 35	* F. 22	* F. 0	* F. -22	* F. -61	* F. -59
1910.....	-70	-70	-51	-34	4	32	33	24	4	-20	-34	-64

In consequence of these low temperatures snow may be expected in the hills at any time. According to Cantwell,¹ the hills in the central part of the Kobuk Valley were snow covered on August 9, 1885. McLenegan states that the Aniuk lowland was partly covered with snow on August 1, 1885, and that the Igichuk Hills "were covered with a heavy fall of snow" on August 8.² On July 14, 1910, freshly fallen snow covered the higher hills between the Kobuk and Noatak, and on July 20, 1910, the hills in the central part of the Kobuk Valley were snow covered down to an elevation of 2,000 feet. In 1911 snow covered the hills opposite the Alatna-Noatak portage on July 24 and the hills east of the canyon of the Noatak on August 15, but the snow disappeared after a few days.

Another effect of the temperature that has an important economic bearing is the opening and closing of the streams. According to Schrader,³ ice was running in the Koyukuk at Peavey on September 20, 1898, and ice broke at the same place May 19, 1899. Stoney⁴ notes that ice had formed on lakes by September 13, 1885; on most of the small streams by September 23; and along the Kobuk by the 25th. By October 18 the main river was frozen so that it could be

¹ Cantwell, J. C., *Exploration of the Kowak River, Alaska; Report of cruise of revenue-marine steamer Curwin in the Arctic Ocean in the year 1885*, Washington, 1887, p. 47.

² McLenegan, S. B., *Exploration of the Noatak River, Alaska; Report of cruise of revenue-marine steamer Curwin in the Arctic Ocean in the year 1885*, Washington, 1887, pp. 70-73.

³ Schrader, F. C., *Twenty-first Ann. Rept. U. S. Geol. Survey*, pt. 2, 1900, p. 459.

⁴ Stoney, G. M., *Naval explorations in Alaska*, p. 52.

crossed. Freezing continued until in February the ice had a thickness of 5½ feet. On May 19, 1886, the ice along the banks of the Kobuk began to crack, and by June 6 the river was free of ice. Joseph Grinnell,¹ who spent the fall of 1898 and the spring of 1899 in the central part of the Kobuk Valley, reports that on October 15 the river was full of ice and that by October 21 the ice was a foot thick. In the following spring the ice began to break on May 24, and by May 31 the river was free. No definite data were secured concerning the time of the freezing or breaking up of the Noatak, but Mendenhall² states that it is reported to free itself ordinarily early in June.

Although the rivers break early in June, it is difficult to reach the region from the United States much before the first of July. Ice in the lakes at the head of the Yukon basin prevents the through passenger boats from running until the middle of June. The last boat down the Koyukuk usually leaves the head of that river by the first week of September. Approach to the region by Bering Sea and the Arctic Ocean can not be made even as early as by way of the Koyukuk, for Kotzebue Sound usually does not open before the first week or so of July. Stoney stated that in 1885 the ice remained in Hotham Inlet as late as July 8. Grinnell³ notes that in 1898 it was impossible to land at Cape Blossom before July 13 on account of the ice in Kotzebue Sound, but in 1899 a channel through Hotham Inlet to the mission was open on July 1, and a boat that wintered near Chamisso Island was able to reach Kotzebue on July 8.

PRECIPITATION.

At Allakaket a record of the precipitation since 1908 has been kept by Weather Bureau observers and affords the only instrumental data on the region.

Precipitation, in inches, at Allakaket, 1908 to 1911.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1908.....	1.00	0.67	0.81	0.34	0.44	0.38	1.92	0.80	.....	0.98	0.78	1.85	9.97+
1909.....	.11	.12	.63	.46	.41	2.81	1.35	.92	0.52	.44	.63	1.44	9.84
1910.....	1.62	.15	.52	.53	.50	1.63	2.62	1.55	.82	.50	.16	.28	10.68
1911.....	.65	2.05	.38	.....	.....	.29	2.24	1.59	1.41	.22	.38	1.04	10.26+
Average.....	.84	.75	.58	.44+	.45+	1.28	2.03	1.21	.92+	.53	.49	1.15	10.67+

The total for the year and the average for the different months have been computed in the same way as for the temperatures in the table on page 38. The average for the entire period has been determined by totaling the monthly averages. From this table it will be

¹ Grinnell, Joseph, *Gold hunting in Alaska*, Chicago, 1901, pp. 79-84.

² Mendenhall, W. C., *Reconnaissance from Fort Hamlin to Kotzebue Sound, Alaska*: Prof. Paper U. S. Geol. Survey No. 10, 1902, p. 54.

³ Grinnell, Joseph, *op. cit.*, p. 13.

seen that at the mouth of the Alatna there is a precipitation of 9 to 11 inches a year. In spite of this apparent aridity, so much of the precipitation comes in the summer that the tourist gains the impression of a much wetter climate than is actually the case. It should be stated, however, that the records of the Weather Bureau station at Allakaket can not be applied to the entire region indiscriminately. Not only do the records cover too short a period, but it is a generally recognized fact that highland areas receive more precipitation than lower country. In the vicinity of Nome, where gages have been installed both in the highlands and on the coast, the precipitation has been from 50 to 250 per cent more in the higher than in the lower region.

Some idea of the precipitation may also be gained by noninstrumental observations by travelers. An attempt was made to determine from McLanegan's account of his trip the kind of weather he experienced from July 2 to August 11, 1885. Although the statements are not full enough for an accurate determination, it appears that of the 40 days he was in the Noatak basin 15 were partly rainy. During the 25 days that Lieut. Allen¹ was in the Koyukuk region in the same year, a summary of his observations gives the following facts:

Meteorologic notes of Lieut. Allen's expedition in the Koyukuk region, 1885.

	Nuklukyet to Koyukuk River.	Koyukuk River to Yukon River.
Total days.....	7	18
Clear days.....	1	0
Fair days.....	0	5
Cloudy days.....	6	13
Rainy days.....	3	6

In 1901 Schrader, on his expedition up John River, reported 11 partly rainy days in the 39 days he was in the region between the mouth of the Alatna and the Koyukuk-Arctic Ocean divide.

Smith reported that, in 1910, of the 72 days he spent in the region between the Koyukuk and the Kobuk and in the valley of the Kobuk 44 were partly rainy. From June 26 to September 1, 1911, a total of 64 days, 37 were partly rainy. It should be noted, however, that much of the rain came in slight showers, which did not last long. This was particularly true in the lower part of the Alatna Valley, where thunderstorms lasting an hour or so occurred almost every afternoon.

The following table gives the records of the snowfall observed at Allakaket during the years 1908 to 1911, so far as they have been furnished by the Weather Bureau:

¹ Allen, H. T., Report of an expedition to the Copper, Tanana, and Koyukuk rivers in the Territory of Alaska in the year 1885, 1887, p. 171.

Snowfall (in inches) at Allakaket, 1908 to 1911.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1908.....										14.0	14.2	31.7
1909.....	2.2	2.8	9.8	7.8		0	0	0	0.8	7.5	11.3	25.0
1910.....	28.0	2.5	8.0	8.2	1.5	0	0	0	1.5	8.0	3.9	5.5
1911.....	9.5	28.0	6.5	16.5	0	0	0	0	0	2.5	4.8	16.6

The snowfall, expressed in terms of its equivalent water, was included in the table of precipitation given on page 40; and therefore the figures given above should not be added to those stated in the other table. A comparison of the snowfall with the total precipitation for each month indicates that the snow is abnormally dry, for it takes from 14 to 16 inches to make an inch of water, whereas the common ratio is about 10 inches of snow to 1 of water. This fact is probably explained by the low temperature, which reduces melting and thus prevents the snow packing closely.

From the record at Allakaket it is evident that the annual snowfall is about 6 feet. This, like the rainfall, is probably less than in the more mountainous parts, although prospectors report that in the Alatna Valley above the Kutuk there is usually so little snow that sledding is at times difficult. Early in June most of the snow on the lowlands has disappeared, but the snow in the protected valleys in the mountains lasts much later and has an important effect in sustaining the flow of the streams. Here and there, where the overflows during the winter have formed considerable thicknesses of ice on the valley floors, the snow and ice may last almost throughout the year. Masses of this sort were noted on July 22 in the upper Alatna Valley at an elevation of 2,000 feet and bade fair to remain throughout the season.

POPULATION AND SETTLEMENTS.

WHITES.

There are only five settlements within the Noatak-Kobuk region. These are Kotzebue, on the coast; Allakaket, on the Koyukuk; the Noatak mission, on Noatak River; and Shungnak and Kiana, in the Kobuk basin.

The most important place is Kotzebue, on the long promontory that separates Hotham Inlet from Kotzebue Sound. This place is the seaport for the entire district, and is normally the home of a missionary and family, three or four white traders, a few boatmen and mechanics, and a number of native families. After the break-up of the ice in the spring, however, missionaries, school-teachers, prospectors, and traders, together with a great number of natives from all the neighboring rivers, congregate for trading and fishing, in

preparation for the coming winter, so that during July a thousand people are camped for 2 or 3 miles along the beach or in the town. Mail service from Nome is maintained by boat every 10 days during the summer and by dog sledge once a month during the winter. Travelers from Nome may reach Kotzebue by the gasoline schooner which serves as the mail boat. The trip takes about three days, as stops are made at way points, and the charges in 1911 were \$25 for each passenger and \$20 a ton for freight.

As has already been stated, Kotzebue is shut off by ice from direct communication with the outside world from the middle of September to the first of July. Even during the open season large vessels from the States can not approach nearer the town than Cape Blossom, an unprotected bluff about 12 miles to the south, because the channel is so narrow, crooked, and shallow that it is not navigable for boats drawing over 6 feet. In consequence of the difficulty of approach, therefore, most goods have to be reshipped, and this adds to the cost of the freight. Supplies of good quality and in amounts to meet the demand, however, can be obtained at the stores in Kotzebue at prices but little in excess of the cost of the same in Seattle plus the freight charges.

The second most important settlement in the region is on the Koyukuk at Allakaket and at Marsans. Although bearing two names, these places are practically one; Allakaket is the site of the mission of St. John in the Wilderness, directly opposite the mouth of the Alatna, and Marsans is the trading post a mile downstream on the west bank of the Koyukuk. Bergman, which used to be an important town in the early days of the Koyukuk gold excitement, has now been abandoned.

The mission is the home of a missionary, who is also the observer for the Weather Bureau and the Government school-teacher, and around it has gathered a native settlement. The number of natives varies during the season, and few of them have built permanent houses but live instead in tents. At Marsans there is only the storekeeper and his family and a few natives. As this post had been but recently installed, a complete stock of goods was not on hand. Prices, however, are reported to be reasonable and the quality of the articles good. Communication is by boat during the short summer and by an overland dog sledge route that reaches the Yukon near the mouth of the Tanana during the winter. The post office is at Bettles, but mail is also delivered en route. The nearest telegraph station is at the Government post at Fort Gibbon. The first boat of the season seldom reaches Allakaket much before July 1, and the last steamer down the river leaves not later than the second week of September.

The Noatak mission is the third largest settlement in the region. It is located on the west bank of the river, about 50 miles in an air

line north of Kotzebue. The river at this place swings against a bluff 50 feet in height, and the settlement has been located on the upland. Practically the only white people at the mission are the missionary, his wife, and three children, but a native population of a score of families has congregated there, and many of them have built permanent log cabins. The buildings of both the whites and the natives are substantial and well made. A new schoolhouse was planned and was probably completed before the winter of 1911.

On the Kobuk are two small settlements, Shungnak and Kiana. Shungnak, which is near the site of Stoney's headquarters at Fort Cosmos, is a small settlement, consisting of a Friends' mission, schoolhouse, store, and the usual native huts. Formerly it was the headquarters of the United States commissioner and recorder for the Noatak-Kobuk precinct, but that office has been removed to Kiana. The store carries only a small stock of supplies for local needs and would not be able to supply a large district. Several prospectors live within 3 to 15 miles of the town on the various creeks, but there are not more than a dozen white people in an area of several thousand square miles.

Kiana is a small settlement at the junction of Squirrel River and the Kobuk. It started practically with the discovery of gold in the vicinity in the fall of 1909, although a native village had been located there previously. At the time the town was visited in August, 1910, it consisted of about a score of log cabins, a store, and restaurant, and had a native population comprising many families. It is understood, however, that during the winter of 1910-11 two more stores were opened, the recorder's office was established, and several more houses were built.

In addition to these larger settlements, prospectors' cabins are scattered here and there, most of them being unoccupied. The topographic map (Pl. I) shows the location of all the known cabins, but there are probably others, so hidden or so remote from the route traveled that they escaped notice. Many of the cabins are in good repair and might afford shelter for travelers. The deserted cabins, however, have been so thoroughly emptied that usually no supplies or even cooking utensils can be found in them. The only isolated cabins that were occupied at the time of the visit by the Survey geologist, except those near the settlements, were on Kutuk and Malemute rivers, both in the Alatna River basin.

An estimate of the total white population of the Noatak-Kobuk region was made incidental to the more direct objects of the expeditions, and although little accuracy may be claimed it is fairly certain that less than 250 white people reside within the basins of these streams.

NATIVES.

Each of the larger settlements of whites has on its outskirts an encampment of natives and these are at present the largest native villages. Kotzebue is the largest town, and here natives from places on the coast as far as Cape Espenberg and Point Hope and from Buckland, Selawik, Kobuk, and Noatak rivers meet to trade and fish, returning to their homes in the fall. At Allakaket natives from the Koyukuk and its branches congregate with those from the Kobuk and the Colville.

At present there are almost no native settlements remote from the villages of the whites. Here and there are isolated huts or hunting lodges used by one or more families, but these are not common. Formerly, however, there were large native settlements in the more remote parts. Stoney notes that on the Kutuk in the Alatna River basin there was a settlement called Nimiuk (meaning cottonwood) about 20 miles above the mouth.¹ Another settlement of the same name was described by the same writer on the upper part of the Noatak, probably near the camp of August 2 of the expedition of 1911. This was reported to consist of four huts occupied by about 30 natives and was the highest village on the Noatak. McLenegan does not mention passing any occupied native villages in his trip up this river, but states that "the greater portion of the inhabitants reside near the extreme headwaters of the river, to which place they repair on the approach of winter * * *. During the summer months they wander up and down the river, spending much of the time in fishing and providing for the needs of the coming winter."²

At the camp of August 7 several abandoned huts, most of which had caved in, and boat frames and coverings showed that the site had once been the home of a considerable native settlement. It was evident, however, that the place had not been occupied for many years except by passing natives. None of the coast natives remembered any permanent settlement at this place, although its location was well known because of the peculiar loop of the river near there, which they called Okuk, meaning tongue. Farther downstream at several places sites of old native settlements were seen, especially near the camp of August 18 and at the camp of August 23. Below the camp of August 19 natives were met almost every day traveling in their skin boats homeward to the mission.

In the Kobuk Valley there are reports and indications of numerous old settlements of natives, but at the present time outside of the native villages at Shungnak (or Long Beach, as the native town

¹ Stoney, G. M., *Naval explorations in Alaska*, Annapolis, 1900, p. 44.

² McLenegan, S. B., *Exploration of the Noatak River, Alaska; Report of cruise of the revenue-marine steamer Corwin in the Arctic Ocean in the year 1886*, Washington, 1887, p. 75.

is called) and at Kiana there are only two that deserve mention, Oksik and Kalla. The former is situated a short distance below Squirrel River, near the place where the Kobuk divides into the northern and middle channels. It is reported to be the largest town in the lower part of the river, but at the time it was seen by the writer most of the inhabitants were at Kotzebue. Kalla is about 7 miles above Shungnak and is the place where most of the salmon fishing in the upper river is done. The natives from Shungnak congregate there in August, but during the rest of the season it is practically deserted.

Of the old villages that are now abandoned, the settlement at the mouth of Pah River was probably one of the most important. Near Stoney's old camp a considerable settlement used to exist, but the place, called Riley Camp, is now practically deserted except for one or two families. Stoney mentions a village in the headwater region of the Ambler, but nothing could be learned of its existence at the present time. Scattered camps here and there along the river were noted, but few of them indicated long occupancy by more than one or two families.

In all the writer's experiences with the natives he has been received with the greatest cordiality, respect, and interest. The older men did their utmost to impart their knowledge of the country and were skillful in describing and depicting the region in which they had traveled. Their ability to read topographic maps and their delight in recognizing on our map regions that they had visited is extraordinary. Physically the men are well developed and active; the younger ones are interested in sports and games, of which they have quite a number. The women are not so active and age early; this, however, does not prevent their carrying babies on their backs and at the same time "mushing" the dogs when tracking, pulling oars when in the boat, or cooking, fishing, and doing other work when in camp. Mentally both sexes are alert and attentive, although their lack of knowledge of English gives them on casual acquaintance an appearance of stupidity.

The summer is a particularly unfavorable time to make an estimate of the number of natives, as many are then away from home. In 1901 Schrader estimated that there were less than 200 natives in the Koyukuk basin and of that number only a small part should be assigned to the region covered by this report. Petrof,¹ in the census of 1880, gives the population of the Noatagamute (people of the Noatak) villages inland on the Noatak River as 400, but McLene-gan² "places the number at 225, which it is thought fully covers the total population."

¹ Petrof, I., Tenth Census, vol. 8, p. 2.

² McLene-gan, S. B., *op. cit.*, pp. 75-76.

The results obtained by the census of 1910 have not yet been published in such form as to show the number of natives in the different villages and drainage basins. According to the figures available, the population of Kotzebue was 193, of Noatak village 121, and of Shungnak 210. Natives probably constitute at least three-quarters of this number, and it is doubtful if more than a hundred others live within the limits of the three basins treated in this report. The census states that for the whole of Alaska the density of population is one person to each 10 square miles of territory. If this figure is correct, it is probable that in northwestern Alaska the ratio is not much over one person to 40 square miles of territory.

ANIMALS AND VEGETATION.

ALATNA RIVER BASIN.

In the southern part of the Alatna basin few signs of game were seen. The absence is probably due to the fact that the natives have long hunted in this part and have gradually killed off the animals or driven them into less accessible regions. In the fall, however, the sloughs and ponds near the river are said to be fairly alive with ducks and geese. Farther upstream game is more abundant and varied. Around Lake Takahula ptarmigan were so numerous that they might be relied on for food. At other places still farther upstream ptarmigan were plentiful and were sufficiently large by the middle of July to be eaten. All were rather wild and should be hunted with a shotgun rather than with a rifle. Toward the head of the river larger game became more abundant. Sheep were found in the valley of the small tributary from the west below the Kutuk, and prospectors report that sheep are also plentiful in the hills at the head of the Kutuk and Nahtuk. Other bands of sheep were seen in the hills around the Noatak-Alatna divide and also east of Alatna River near the camp of July 22. In July the females were not in good flesh, but at that time the males are reported to be in their prime. Not many bears were seen, but evidence of their presence was common. They are reported to be mainly black; the only ones seen were of this color. Mendenhall¹ states that moose are known to the natives as far north as Chandler Lake in the Colville drainage basin, but no moose nor even signs of them were seen in the Alatna basin.

Fish are fairly abundant in the main stream and its tributaries. Salmon are reported to be caught in considerable numbers in the lower Alatna, but farther upstream grayling and whitefish are more abundant. These fish are caught and dried by the natives and form an important part of their winter's food supply. Pike were shot

¹ Mendenhall, W. C., Reconnaissance from Fort Hamlin to Kotzebue Sound, Alaska: Prof. Paper U. S. Geol. Survey No. 10, 1902, p. 55.

along the border of Lake Takahula as they were lying in the marsh grass. Suckers were caught at several places but did not appear to be very abundant. In Helpmejack Creek grayling were so numerous that they could be caught nearly as rapidly as the fly was dropped into the water. It is also interesting to note that fish were very abundant in the lakes on the Alatna-Noatak divide at the camp of July 25. It seems impossible that they could have reached the lakes by swimming, as the streams in their upper part are extremely steep and contain almost no water. It is believed that fish are sufficiently abundant throughout most of the region so that they could be relied on to furnish food for travelers and prospectors for a considerable time.

The vegetation of the Alatna Valley is typically sub-Arctic and Arctic in its character. In the lowlands trees and bushes are plentiful, but in the higher regions vegetation gradually disappears upslope, until on the peaks and the crests of the ridges even grasses are practically absent. Spruce is found along the valley as far as the camp of July 22, and its general distribution is graphically shown by figure 1. In the southern part of the basin the trees average 10 to 12 inches in diameter and extend up the slopes to an elevation of 2,000 to 2,500 feet, but the diameter of the trees and the elevation of the upper border of the forested zone gradually decrease northward until at the camp of July 20 the diameter of the trees is only 6 to 8 inches and even scattered trees do not extend more than 500 to 600 feet above the river. The northern limit of trees is so sharply defined as to make a decidedly abrupt break which seems to have been controlled by some other factors than temperature and elevation.

The general appearance of the vegetation north of the region in which spruce grows is fairly well indicated by Plate VII, A, a view looking north from the camp of July 23. Even willow and alder are scarce, and camp sites must be carefully chosen in order to get sufficient fuel for cooking. The same general kind of vegetation appears farther downstream in the small tributary valleys and above the belt of trees on the slopes of the main valley walls. In these treeless areas numerous brilliantly colored flowers add much to the landscape; for instance, near the camp of July 18 the eastern hillside for an area of nearly 2 square miles was so ablaze with fireweed that the color attracted attention for many miles. Blueberries and cranberries are also abundant in these open areas and form important additions to the available local food supply.

Grass for stock is sufficiently abundant for traveling pack animals, but the amount is not enough to permit the permanent pasturage of any considerable number. Schrader,¹ however, states that a horse is

¹ Schrader, F. C., A reconnaissance in northern Alaska across the Rocky Mountains, along Koyukuk, John, Anaktuvuk, and Colville rivers, and the Arctic coast to Cape Lisburne, in 1901: Prof. Paper U. S. Geol. Survey No. 20, 1904, p. 20.

A map of the Arctic region, showing the Unexplored but probably timberless area. The map includes the Arctic Circle, the North Pole, and various rivers and islands. The area is labeled "Unexplored but probably timberless" and "Unexplored". The map also shows the "Arctic Circle" and "North Pole".

¹ Maddren, A. G., oral communication.

lower hill slopes and the horsetail grass (*equisetum*), which is found in well-drained fertile soils on bars or at the edges of open spaces, are relished by horses and seem to be the best. Redtop grass is particularly abundant around old cabins and settlements, but although it grows luxuriantly it does not seem to have the amount of nourishment that the tougher, smaller, less abundant grasses possess.

NOATAK RIVER BASIN.

Game in the Noatak region is on the whole more abundant than it is in the Alatna Valley. Sheep are so numerous in the headwater mountains that natives from places as far away as the Kobuk make annual trips to them for their winter's supply of meat. Near the camp of August 1 four natives from the Kobuk were met on such a hunting trip, and many sheep horns discarded by other hunting expeditions were found along the banks of Twelvemile Creek. Ipmiluik, the name of the river that joins the Noatak near the camp of August 1, means sheep, and refers to the fact that this is the route followed on the journey from the Kobuk after sheep. On the hill opposite the mouth of Twelvemile Creek, near the head of the Noatak, sheep trails are so numerous that the zigzag lines can be seen for several miles. Sheep were also obtained on the hill on the south side of the river opposite the mouth of Midas Creek. Some indications of bear were seen, but none of these animals were encountered. Wolverine was seen in the valley of the creek leading to the Alatna-Noatak portage. Fox, mink, and squirrel were also seen.

In the Aniuk lowland caribou are fairly numerous, and natives from the lower part of the Noatak as well as from the Kobuk make annual hunting trips to this part of the region. Early in August the bucks are in prime condition and have been so little hunted that with care they can be approached without alarming them. Fox, marten, and wolves were numerous, judging from the tracks on the sandy and muddy shores. Two cross-foxes were seen from the boat at a distance of only 25 to 50 feet. Birds did not seem to be very numerous, but the piles of ptarmigan bones around the many hawks' nests that were examined indicated that there were many more than we had suspected.

In the second highland and farther downstream caribou and sheep are practically absent near the river; bears, however, are much more numerous, and their trails can be found on almost every sand bar. No bears were seen, but from the size of the footprints it is judged that they are mostly the brown variety. In the mission lowland both land and water birds are much more numerous. Ptarmigan in flocks of 10 to 50 were found in the low country, and ducks, geese, and cranes were commencing to flock for their migration and could be seen on the lakes and sloughs by the latter part of August. Near the camp of August 23 birds were particularly plentiful.

A flock of 35 crane was counted, and flocks of 50 or more geese were by no means uncommon. In the river a short distance above this camp and for a considerable distance below seal in great numbers lay in the shallow water, looking at a distance like masses of sand.

The fish noted in the Noatak were in general the same as those in the Alatna. Salmon form an important part of the local food supply, and a few were seen on the drying frames at the native camp. They were not very numerous, and it is believed that many of the natives go to Kotzebue to catch their fish, as the farther the fish have traveled in fresh water the poorer they are said to be. McLenegan¹ noted that near the eastern margin of the second highlands there was a fishing village that was occupied only during the salmon run. The members of the expedition of 1911 were able to shoot so much fresh meat that they spent no time in fishing in any of the Noatak streams. It is believed, however, that these streams, like most of those in northern Alaska, have grayling and trout in sufficient number to be of considerable value to prospectors and travelers.

The greater part of the Noatak basin is timberless, and this will make the development of the region difficult. The most eastern spruce in the Noatak Valley, as shown in figure 1, is between the camps of August 13 and 14. At this place trees 8 to 12 inches in diameter appear along the well-drained banks of the river as a narrow fringe. Farther downstream spruce may be found almost everywhere in the immediate vicinity of the river to a point a short distance below the camp of August 26, at the mouth, where it is again absent. Over much of the swampy lowland back from the streams and on the hill slopes timber is absent, even in the western part of the valley. The large size and sturdy growth of the trees, even near the borders of the unforested areas, is striking. Fully as large and vigorous trees were seen within 15 miles of the extreme eastern limit of timber as anywhere else in the region, although the place was fully as high, as much exposed, and had a soil not differing radically from that of the neighboring tracts. That the frozen condition of the soil is not a dominating influence is shown by Plate XII, *B*, where a good stand of spruce may be seen growing almost immediately on top of clear ice.

Although spruce or other large trees are absent, some bushes large enough for fuel grow even in the headwater portions of the valley. Willow, alder, and poplar (cottonwood and balm of Gilead) were seen in the valley above the camp of August 2, and farther downstream they become more abundant and larger. In places the poplars are 6 inches in diameter and 20 feet high. These bushes are used by the natives on the upper river for frameworks for their huts. After the frame has been woven and twisted together sods, old boat coverings, and other materials are placed on top and chinked with earth and moss so as to form a serviceable shelter. In places fish nets are made from

¹ McLenegan, *B. B.*, op. cit., p. 68.

twisted fibers of willow, which is used by certain of the inland natives for all purposes for which twine would ordinarily be employed.

Feed for stock is not abundant and frost comes so early that the season during which animals can obtain sufficient forage is very short. It is believed, however, that the supply is adequate for a few animals, such as a Survey pack train traveling rather rapidly through the country—but not sufficient to sustain the strength of the animals for a long period. Reindeer moss is particularly abundant in the better-drained lowland areas, especially those near Aniak and Cutler rivers, and on the hill slopes a short distance back from the coast. These hill slopes have been used as the feeding ground for the herd of reindeer introduced by the Government, which ranges between the mouth of the Noatak and Cape Krusenstern.

Berries are generally plentiful in the lowland areas and form an important part of the local food supply of both natives and whites. Blueberries, cranberries, currants, and salmon berries are most abundant and owing to the cold climate can be picked in the fall and kept through the winter without deterioration.

KOBUK RIVER BASIN.

Throughout the greater part of the surveyed area near the Kobuk game is not plentiful. Caribou have been reported in the region, but none were seen by any of the Survey parties. There is, however, a herd of reindeer in the vicinity of the Sheklukshuk Hills, and it is possible that some of the stray deer have been mistaken for caribou. Bears are practically the only large wild animals. Those seen were black, but brown bears are said to be fairly numerous in the more remote parts of the basin. Sheep may probably be found in the head-water mountains, though the fact that the Kobuk natives make trips to the head of the Noatak for their supply of this meat indicates that these animals are not abundant nearer home. Moose are reported to have been found in the Kobuk Valley in the early days, but no signs of them were seen by Mendenhall or by the expedition of 1910. Small animals, such as foxes, marten, mink, and lynx, used to be fairly common but are yearly becoming scarcer. Muskrats are very numerous in the delta portion of the river.

Ptarmigan, spruce hens, ducks, and geese are the birds most commonly hunted by prospectors, and it is said that they are still sufficiently numerous to be relied on for food. The land birds are found mainly in the Squirrel River to Reed River province, but the water fowl are most abundant in the delta. Other birds are common throughout the region. A fairly complete list of the birds observed in this region has been prepared by Joseph Grinnell.¹

¹ Grinnell, Joseph, *Birds of the Kotzebue Sound region, Alaska*: Cooper Ornithological Club, California, vol. 1, No. 1, 1900.

Fish are abundant in almost all the streams. Salmon is the most important as a food supply. These fish are particularly abundant as far up as Lake Selby, and during the fishing season drying frames may be seen at many places along the river. In the central part of the Kobuk basin the main native fishing camp is at Kalla, near the mouth of Kollyoksok Creek, a short distance above Shungnak. In addition to salmon a large white fish, known to the natives as "she," is also obtained in the Kobuk and in some of the larger lakes and is much prized for food. Grayling can be found in almost all the side streams and mountain brooks. Trout, probably the salmon trout, weighing as much as 3 or 4 pounds, were caught near Shungnak and are reported from many of the neighboring streams. Mendenhall¹ states that "numbers of pike are caught, especially in the delta of the Kobuk and in the sloughs of this and other streams, where there is but little current and water plants flourish."

Timber is found mainly along the larger streams, and, as indicated in figure 1, does not extend up the mountain slopes to elevations of more than 2,000 feet in the eastern part of the basin, the upper limit gradually decreasing in altitude toward the west. On the flats in the central part of the basin trees are usually absent, except in scattered clumps here and there where the upland is not too swampy. In the lower part of the delta trees are absent. Spruce and birch are the only trees that grow to sufficient size for lumber, and only the spruce is large enough for cabin logs. Stoney² notes that the largest spruce tree seen by him in the entire Kobuk Valley was near Cosmos Creek. It measured 80 inches in circumference at the base and 68 inches at a height of 6 feet above the ground and was 80 feet tall. This was an unusually large tree, however, and the average spruce does not exceed a foot in diameter. The birches grow on the low hillsides, except the prostrate variety, which occurs high on the valley sides. Willows and alders are abundant throughout the basin, except high on the ridges, and may be relied on as sources of fuel where trees are absent.

Grasses for stock are found on the lower hill slopes and on the lowlands. Mendenhall³ notes rye grass, blue grass or red top, and a variety of bunch grass as the more usual species. The grasses flourish, particularly in the neighborhood of old settlements and camps, and quickly spring up in burned-over areas, but none of them seem to stand frost well, for all appear to wither and lose their nutriment as soon as freezing nights begin. Even when the grass is unwithered it is very watery, and the stock used on the expedition of 1910 grew constantly weaker, although there was an abundance of what appeared to be good grass.

¹ Mendenhall, W. C., Reconnaissance from Fort Hamlin to Kotzebue Sound, Alaska: Prof. Paper U. S. Geol. Survey No. 10, 1902, p. 55.

² Stoney, G. M., Naval explorations in Alaska, Annapolis, 1900, p. 82.

³ Mendenhall, W. C., op. cit., p. 57.

Alatna and Noatak rivers. They probably also form a large part of the unexplored highlands between the Noatak and Kobuk and between Alatna and John rivers. In the unexplored areas east of Buckland River and south of latitude 67° N. there are probably none of these rocks. Little is known of the region north of the Noatak, so that it is rather unsafe to predict the kind of rocks that occur in the unexplored tracts, but from the best evidence at hand it seems improbable that extensive exposures of these rocks occur north of latitude 68° .

The rocks therefore generally lie in a belt not over 70 miles wide, trending east and west in the eastern part of the Noatak-Kobuk region and then swinging rather abruptly until in Seward Peninsula the trend is nearly north and south. This belt is closely parallel to the marked structural trends that are better known in southern Alaska. It may be noted here that, although the metamorphic rocks have the surface distribution indicated, they may also occur deeply buried throughout the mapped area. Conversely, in those places where pronounced folding or faulting has raised certain of the overlying rocks high above the present plane of erosion, these older schists may outcrop at the surface.

LITHOLOGIC CHARACTER.

The undifferentiated metamorphic rocks cover a large territory and exhibit a correspondingly wide range of lithologic character, but are a unit in that all of them are much sheared and foliated and are schistose. Dominantly they are of a gray or grayish-green color, though black and brown beds are here and there found where carbonaceous material or iron oxides are abundant. The schists are not strongly resistant to weathering, but as they occur in the axes of greatest deformation they usually form rugged hills which have had their steepness emphasized by relatively recent glacial sculpturing.

Numerous subdivisions of the undifferentiated metamorphic schists will undoubtedly be made when the rocks are studied in greater detail. Differences in chemical composition have been observed and afford a basis for separation that would probably have stratigraphic value. The data at hand are not sufficient to afford a means of discriminating the various facies, but a statement of the several types may be made.

Considered as to size of grain, the rocks may be divided into schists and conglomerates. The schists predominate and may be still further divided from the most prominent mineral into quartzose schists, calcareous schists, carbonaceous schists, and chloritic schists.

The quartzose schists have been reported everywhere within the area of the metamorphic schists. As the name implies, these rocks consist dominantly of quartz. Plate VIII, A, shows a typical expo-



A. TYPICAL OUTCROP OF SCHIST, ALATNA RIVER.



B. SCHISTOSE CONGLOMERATE FROM DAHL CREEK, KOBUK RIVER.

sure of the quartzose schists in the central part of the Alatna Valley and might be duplicated from any region where these rocks occur. The quartzose schists are usually rather fine grained, much cleaved, and show a considerable development of foliate minerals, notably chlorite and muscovite. Biotite, however, is usually absent, except in the vicinity of granitic intrusives. The schists rarely show any original bedding structures, but two or more secondary cleavages are by no means uncommon. Under the microscope feldspar fragments may be recognized in certain sections, but they are of small size and constitute only a small proportion of the rock. Gradations between the quartzose and other phases of the schist have been seen and in such places the quartzose schists take on more and more the characters of the other facies.

The calcareous schists are similar to the quartzose schists in general metamorphic character, but contain abundant calcite and notably less quartz. These schists range from rocks of rather fine grain, in which the presence of calcite can be detected in the field only by the use of acid, to yellowish rather coarsely crystalline rocks composed mainly of calcite, with scattering flakes of chlorite and mica. The latter phase appears to have been recrystallized under static conditions; its original structures are not preserved, and it generally shows not more than one secondary structure. These rocks appear interlaminated with the quartzose schists and the other types. In some places, however, the field relations are such as to suggest that they have been derived through the dynamic metamorphism of limestones that were originally present in this group. Few calcareous schists were noted in the basins of John or Alatna rivers, but they are common in the Kobuk basin and in Seward Peninsula.

Carbonaceous schists and quartzites have been reported throughout the area of metamorphic rocks. They are dominantly quartzose, but on the whole seem to have been somewhat less sheared than the other metamorphic rocks. In many of the specimens the carbonaceous material occurs in the form of graphite, but in others it is in such a fine dustlike condition that its specific character has not been determined. Many of the carbonaceous schists and slates closely resemble certain of the Seward Peninsula rocks, notably the Hurrah slate¹ of the Solomon-Casadepaga region and the Kuzitrin formation,² dominant in the central part of the peninsula. In most places there are a great number of quartz veins and lenses in the carbonaceous slates and quartzites ranging from microscopic filaments to masses 2 or 3 feet in width and traceable for several hundred feet along the strike.

¹ Smith, P. S., *Geology and mineral resources of the Solomon and Casadepaga quadrangles*: Bull. U. S. Geol. Survey No. 433, 1906, pp. 59-62.

² Collier, A. J., and others, *The gold placers of parts of Seward Peninsula, Alaska*: Bull. U. S. Geol. Survey No. 328, 1906, pp. 69-70.

The chloritic schists are not so distinct as the others enumerated and are probably closely allied to the quartzose schists. They contain relatively less quartz and proportionately more chlorite, and in extreme examples chlorite is practically the only mineral recognized macroscopically. Under the microscope, however, quartz, zoisite, a little calcite, and some feldspar may be recognized.

Feldspathic schists, so common in parts of Seward Peninsula, have not been found in any large quantity in the Noatak-Kobuk region, though here and there small exposures of this type of rock have been observed. Garnetiferous schists have also been found but sparingly. Mr. L. M. Prindle, who spent a winter in the central part of the Kobuk basin, says that the rocks in the mountains north of the Ambler-Kogoluktuk lowland are in places highly garnetiferous.

The conglomerate phase of the undifferentiated metamorphic rocks has been observed at only two places—one along the south face of the Cosmos Hills near Shungnak, in the Kobuk basin, and the other nearly north of this place, between the camps of August 3 and August 4, on the Noatak. The conglomerate in the Kobuk locality occupies a strip about 2 miles wide, trending in an east-west direction, and dips southward. Although the relations to the other metamorphic rocks are not perfectly clear, the dip indicates that the conglomerate overlies the schists and slates to the north. Further evidence in support of this view is afforded by the fact that recognizable pebbles of black slate and of chloritic schist, together with numerous quartz pebbles, make up the conglomerate. These pebbles prove by their presence that schists, slates, and quartz veins were in existence and had been eroded before the deposition of the conglomerate, and they suggest an unconformable relation between these rocks and the conglomerate.

Other conglomerates of younger age will be noted later, but it should be distinctly understood that the one described above is thoroughly sheared and schistose throughout its extent and can in no way be explained by the lesser amount of deformation to which the later conglomerate has been subjected. This may be clearly seen by reference to Plate VIII, *B*, which shows three specimens of the metamorphic conglomerate. Not only have the pebbles composed of the softer rocks been deformed but even the quartz pebbles (shown best by the light-colored portion of the specimen farthest to the right) have been so pulled out and elongated that they are now many times their original length. It should be noted, however, that the pebbles shown on this plate by no means represent the maximum distortion, for by excessive elongation the pebble form becomes more and more obliterated, so that finally it can not be recognized. Therefore, many of the patches of quartz of no definite shape or distribution seen in the specimen may have been once distinct pebbles but are now stretched and shattered beyond recognition.

The schistose conglomerate from the Noatak was not seen in place but was found only as float. The localized distribution of this material, the lack of thorough water rounding, and the size and freshness of the specimens, all suggest that the float had not been transported far. Lithologically the rock is identical with that found in the Kobuk basin, but it contains somewhat less vein quartz and is rather finer grained.

STRUCTURE.

The lack of detailed studies of the extremely complex stratigraphy of the undifferentiated metamorphic rocks prevents determination of their structure. The distribution effected by the most recent diastrophic movement has already been described, but the structure that preceded this stage still remains undetermined. That there were two or more periods of diastrophism before the one that produced the present major structure seems clearly indicated, but the direction and extent of these movements is unknown. During the latest pronounced period of deformation the rocks were thrown into a series of east-west folds and broken by faults in the eastern part of the field, whereas north-south folds and faults were formed in the western part. Dislocations having an enormous throw must be postulated to account for the observed distribution of the rocks, and abnormal relations through overturning may be found in practically all parts of the field. The relation to the other rocks is therefore in places obscure or antithetical and isolated structural observations are often misleading. As a result of the extremely complex structure estimates of thickness are little better than guesses, but tens of thousands of feet of strata must be included in the undifferentiated schists.

Although it is impossible to express the major structure from the facts available, the smaller structures are prominent and may be seen in all exposures if carefully sought. As stated, the prominent structure everywhere observable is cleavage. So strongly marked is this feature that rarely if ever is the original structure of the rock determinable. In many exposures not only one but several structures due to deformation are visible. Thus it is no uncommon thing to see examples of folding and shearing of earlier cleavage planes by later deformation. This feature is recognizable even in Plate VIII, A, and is much more evident in the actual exposure.

Faults of small displacement may be recognized almost anywhere, and most of them appear to be of the thrust type. Larger faults probably occur, but the absence of easily recognizable guide horizons and the probability of unconformities between the schists and the younger rocks make precise determination of the amount of displacement impossible without considerably more detailed study. Slickensiding along the fault planes is common, but a large part of the dislocation was probably taken up by small movements along the cleavage planes and therefore the amount is undetermined.

These features, as stated before, are recognizable in all the members of the undifferentiated schists, but they are most prominent in the quartzose schists and least so in the calcareous schists and in the dark carbonaceous slates and quartzites. This difference may perhaps be due to difference in the age, but it may also be due to the fact that the calcareous schists are least resistant and therefore easily readjust themselves to stresses, whereas the carbonaceous quartzites and slates are more resistant and therefore withstood deformation best, and the quartzose schists, intermediate between the two, were easily deformed but were resistant enough to preserve more traces of their earlier condition.

AGE AND INTERRELATIONS.

As the undifferentiated metamorphic schists comprise a great thickness and variety of rocks, they probably have a considerable range in age. No fossils have been found in these rocks and therefore their age must be determined by analogies and inferences. Unfortunately, most of the rocks that are closely associated with the schists are also unfossiliferous, so that many of the correlations rest on analogies with areas far away, and in a region having a structure so complex as that of the Noatak-Kobuk region these analogies are liable to lead to considerable error. In Seward Peninsula the supposed equivalent schists underlie rocks of known Ordovician age and probably underlie Cambrian rocks unconformably, if judged by the difference in physical character. On John River Schrader's section shows the Totzen "series," that is the equivalent of the undifferentiated metamorphic rocks farther west, overlying limestones (the Skajit formation) containing indistinct fossils that are stated to be not older than Silurian nor younger than Carboniferous. Brooks, however, says:¹

The contact between these rocks and the Skajit was not exposed, but Schrader appears to have regarded the Totzen as the younger, though his statements on this point ² are not entirely in accord. The evidence presented might almost equally well be interpreted as indicating that the Totzen underlies the Skajit.

On Alatna River the schists underlie unconformably a similar limestone and therefore are older than the Skajit formation. On Dahl Creek in the Kobuk basin the schists underlie a limestone that presumably is late Paleozoic, as fossils similar to those in the Devonian and Carboniferous limestones of Seward Peninsula are found in the float that probably came from the limestone. On the Noatak the evidence of age of the schists rests on the correlation of the limestones similar to those exposed on Alatna River. The schists are certainly older than the limestones, but nowhere are the higher rocks fossiliferous.

¹ Brooks, A. H., *Geography and geology of Alaska*: Prof. Paper U. S. Geol. Survey No. 45, 1906, p. 215.

² Schrader, F. C., *A reconnaissance in northern Alaska*: Prof. Paper U. S. Geol. Survey No. 20, 1904, pp. 55-62.

There will be occasion to refer later to the age of these limestones and to point out that probably they are of Paleozoic age. For the present, however, no more definite statement of the age of the schists can be made than that they probably were formed not later than the early Paleozoic and possibly as much earlier as the pre-Paleozoic. This determination is necessarily vague, but it suggests the correlation of these undifferentiated metamorphic rocks with the schistose rocks in the lower part of the Nome group or with the Kigluaik group and Kuzitrin formation of Seward Peninsula, with portions of the Birch Creek schist of the central part of the Yukon basin, and with the "Rapids," "Lake," and amphibolite schists of the Chandalar-Koyukuk region, not to mention other areas more remote.

UNDIFFERENTIATED PALEOZOIC LIMESTONES.

DISTRIBUTION.

The undifferentiated Paleozoic limestones are widely distributed throughout the Noatak-Kobuk region. Plate II shows graphically the places where these rocks have been recognized. From this map it may be seen that there are four more or less distinct large areas of these rocks together with many smaller ones. The four main areas are in the central part of John and Alatna River basins, in the headwaters of the Noatak, in the Igichuk Hills of the lower part of the Noatak basin, and in Seward Peninsula. The smaller areas are most numerous in the Cosmos Hills north of Shungnak and in the hills near the pass between the Kobuk and the Alatna. It is not intended by thus separating the areas of undifferentiated limestones to imply that subsequent investigation may not demonstrate that they are continuous or that some of them are the equivalent of certain differentiated formations or groups. In each of the areas the undifferentiated Paleozoic limestones show certain distinct features which make it desirable to treat the lithologic character, structure, and age of these rocks in each area separately and this plan will be adopted in the following pages.

LITHOLOGIC CHARACTER.

The Paleozoic limestone on John River¹ is described by Schrader as a—

heavy-bedded crystalline limestone and mica schist. Weathered surfaces parallel with the bedding and planes of movement and crushing present a silvery sheen due to the presence of mica, while some layers grade wholly into a mica schist. On a fresh fracture surface the limestone is found to be highly crystalline, generally fine or medium grained, and of impure white or bluish-gray color, the latter apparently denoting the more dolomitic phases of the rock. It weathers to a dirty gray or light brown, sometimes tinged with red.

On Alatna River very similar limestones occur between the camp of July 10 and the mouth of the Pingaluk. In places the limestone is

¹ Schrader, F. C., op. cit., p. 56.

dark and has bluish-white bands; in others it is grayish and has been somewhat silicified; and in still others it is brownish and weathers to a sugary sand. No dolomitic horizons were recognized. Mica is recognizable in all of these phases and in places is so abundant that the rock might be characterized as a calcareous schist. Locally the limestone has been cut by greenstones and tremolite and other contact-metamorphic minerals have been formed.

Plate IX, *A*, a view of the hill east of Alatna River near the camp of July 10, illustrates the characteristic topography of the bare white hills to which the limestones give rise.

North of the Kutuk on Alatna River another band of limestones, about 2 miles wide, trends east and west. On weathered exposure the limestone appears quite brown but on fresh fracture is dark gray and rather less crystalline and schistose than the limestone to the south. This seems to be the eastern continuation of the limestone that occurs in the headward part of the Noatak. In the latter basin, however, the rock is somewhat more schistose and is usually darker on fresh fracture. Plate IX, *B*, which shows a near view of this limestone a short distance below the camp of August 4, illustrates the general physical character of the rock. Bedding is but poorly preserved, the dominant structure being cleavage. Here and there, however, the bedding may be recognized, as may be seen in Plate XIV, *A* (p. 122), a view of an outcrop a short distance below the camp of August 1, which will be described in somewhat greater detail later. The hammer handle is parallel with the bedding; the more prominent structure nearly at right angles to this direction is cleavage developed by the recrystallization of the limestone. Some scattered sulphides occur in the limestone in well-formed crystals. These on weathering stain the rock brown and give rise to most of the local variations in its color.

East of the camp of July 28, near the base of the limestone, there is a reddish limestone somewhat less schistose and more sandy on weathered surfaces than elsewhere. In the gravels of the large stream from the south, a short distance above the camp of July 31, many pieces of float were found having indistinct cylindrical tubes of white color in a dark, nearly black limestone, suggesting nearly obliterated corals.

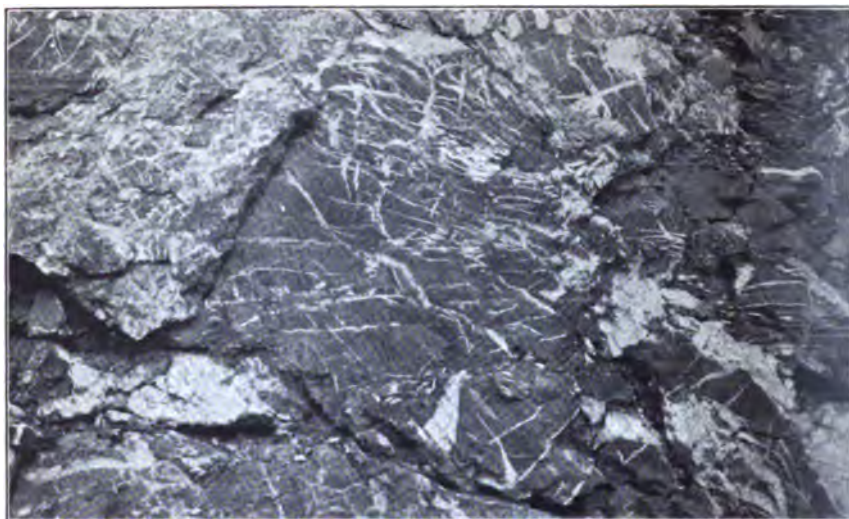
The rocks of the Igichuk Hills have been provisionally classed with the undifferentiated Paleozoic limestones on account of lack of specific data and the absence of features characteristic of certain of the known limestones. These rocks are considerably deformed, and in places present schistose phases with original structures practically unrecognizable. Dolomites are practically absent and the rocks are recrystallized limestones of blue-gray to white color. Some sparsely disseminated sulphides are occasionally found and in places on weathering out have given the surface of the limestone a honey-



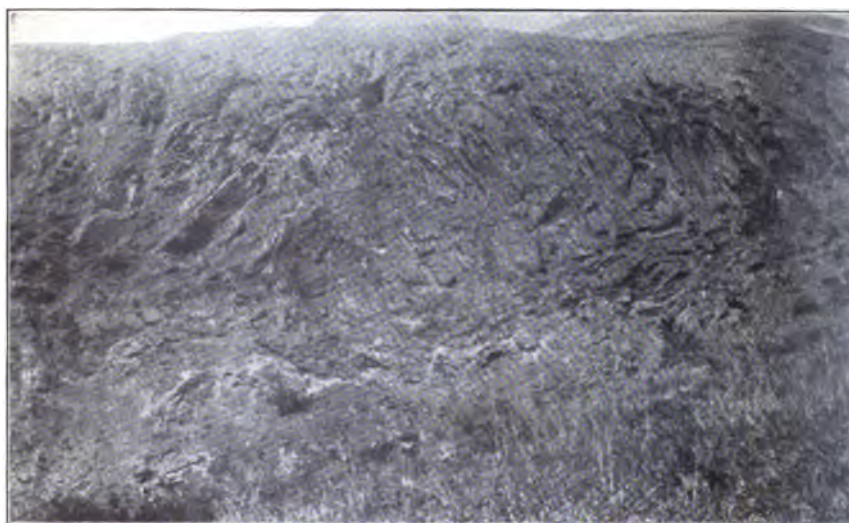
A. TOPOGRAPHY OF LIMESTONE AREA IN CENTRAL PART OF ALATNA RIVER VALLEY.



B. EXPOSURE OF LIMESTONE ON UPPER NOATAK RIVER.



A. FOLDED SANDSTONE CUT BY GASH VEINS, NOATAK RIVER.



B. DEFORMED PALEOZOIC ROCKS, NOATAK RIVER.

combed appearance. Little or no silicification was observed in the rocks and there were no minerals of contact-metamorphic origin. The general appearance of these rocks is fairly well shown by Plate IV, A (p. 28).

In Seward Peninsula the undifferentiated Paleozoic limestones have been most carefully studied by Moffit and from his report¹ the following description is abstracted:

Northeast of the Asses Ears is an area of about 35 square miles [the largest limestone area shown in the extreme southwestern portion of Pl. II], made up chiefly of white marbles much sheeted and sometimes schistose, which appear as smooth, rounded domes, bare of moss, and therefore affording good footing to the traveler. Long radiating needles of tremolite are not uncommon, but otherwise the limestone is generally almost pure. * * *

Black graphitic varieties [of limestone] are not uncommon, especially in the Inmachuk and Goodhope River region.

The smaller areas of undifferentiated Paleozoic limestones in the Kobuk and Alatna basins require no special description, as they are formed of rocks essentially similar to those already described. On the whole, judging from the descriptions of Mendenhall, the limestones appear to be in somewhat narrower belts and to be more interlaminated with schists. It is by no means certain, however, that this interlamination represents depositional differences, as it may be due either to infolding or to regional metamorphism. Although most of the bands of limestone are thinner than those already described the indefinitely located limestone area on Reed River is only part of a considerable exposure of this rock, the boundaries of which could not be determined because of their distance from the observer.

STRUCTURE.

Enough has already been said to show that all the undifferentiated Paleozoic limestones have been considerably deformed and the dominant structure is secondary. Cleavage rather than bedding is the structure observed and only in areas where the structure is exceptionally well preserved is the original bedding recognizable. For this reason, in attempting to determine the general stratigraphy, the areal distribution must be considered far more important than the observations made on minute structural features. Furthermore, observation from a distance usually does not disclose the true condition, and structure that appears simple at a distance becomes more and more complex the closer it is investigated. This fact has already been shown by certain of the foregoing illustrations and is emphasized by others introduced later (Pl. X, B, for instance).

The major structure of the undifferentiated limestones corresponds to the general east-west trend in the eastern part of the field and the

¹ Moffit, F. H., Fairhaven gold placers, Seward Peninsula, Alaska: Bull. U. S. Geol. Survey No. 247, 1905, p. 22.

north-south trend in Seward Peninsula, already noted under the head of the "Undifferentiated metamorphic schists." The limestones, however, show by their continuity and areal distribution that they have not been subjected to the same amount of diastrophism as the schists; in general, they seem to occur as infolded or unfaulted synclines and are unconformable on the undifferentiated schists. This structure is rather clearly indicated in the two belts of limestone in the central part of Alatna River valley. At the southern margin of this area the strike of the schists is nearly north and south and the dip is steep and variable to the east and west, whereas the limestones trend nearly east and west and dip steeply north. At the northern border the structure is not satisfactorily exposed, although the dip seems in general to be northward, as though the schists to the north overlie the limestone. Here and there, however, southward dips were observed and an overturned structure is suggested. Still farther north the narrow belt of limestone dips north on the southern side of the area and south farther upstream, indicating a syncline, a structure which is confirmed by the fact that in several places farther north the limestone caps the hills and the schists form the lower slopes.

The structure of the limestone belt in the upper part of the Noatak region is exceedingly complex and has not been satisfactorily determined. The general dip is apparently northward, but with folding so intricate as that shown in Plate X, *B*, which represents an exposure between the camps of July 31 and August 1, the true structure can be demonstrated only by detailed studies. Furthermore, the rocks in the hills north of Midas Creek (camp of August 2) dip south at high angles, whereas the limestones on the Noatak a short distance above that creek dip north, so that the inferred fault that exists between the two places makes satisfactory proof of the structure impossible, and the rocks farther west are covered by a mantle of alluvium.

The observations made in the Igichuk Hills are not sufficiently extensive to determine the major structure of the limestone in that area. The rocks are intensely deformed and the dips are so nearly vertical and their directions change so unsystematically from place to place that the only generalization possible is that the rocks are nearly on edge and probably form a much shattered and faulted synclitorium.

The structural features of the limestones of Seward Peninsula present some anomalies that can be explained only by further field investigation. Moffit¹ states that some of the massive limestones appear to have been thrust up through the overlying schists, possibly during granitic intrusions. The writer has not seen this feature and feels some hesitation in accepting Moffit's conclusion because of the

¹Moffit, F. H., *op. cit.*, p. 23.

mechanical difficulties involved and the lack of definite proof of the stratigraphic relation of the schists and limestones.

Small structural features recognized in the undifferentiated limestones are faulting, brecciation, recrystallization, and cleavage. The last two have already been sufficiently described. Brecciation is common and gives rise to a peculiar mottled appearance, caused by the fragments of noncrystallized original black limestone being embedded in later infiltrated white crystalline calcite. Much of the brecciation appears to have been effected by shattering unaccompanied by any considerable movement. Faulting on a small scale may be seen in many of the outcrops. The data for determining the amount of dislocation that has taken place are usually obscure except for faults of small throw. Along many of the larger faults the limestone has so flowed under pressure and then recrystallized that the evidence of movement is in large measure masked.

AGE AND INTERRELATIONS.

The Paleozoic limestone on John River contains indistinct fossils, which Prof. Charles Schuchert identified as "having the ventral valve of a brachiopod of the order of *Meristina* and *Meristella* and also resembling a transverse *Seminula*. This kind of shell indicates that the rock can not be older than Upper Silurian and not younger than Lower Carboniferous."¹ Owing to an error in assigning the Carboniferous limestone or Lisburne limestone in the John-Anaktuvuk section to the Devonian, and to the fact that the so-called Skajit formation was more disturbed and metamorphosed than the Lisburne, Schrader provisionally referred the Skajit to the "Upper Silurian" (Silurian). The difference in amount of metamorphism is not conclusive evidence, for the deformation seems to become progressively less toward the north. Schrader in his published report made no distinction between the rocks underlying the Lisburne limestone and those supposed to overlie the Skajit formation. Studies in the Alatna River basin indicate that the equivalent of the Skajit formation overlies the schist, and from a reexamination of Schrader's notes it was found that the rocks underlying the Lisburne limestone are less schistose than those supposed to overlie the Skajit. It is therefore a problem whether or not the Skajit and the Lisburne should be correlated. The only fact opposed to such a correlation is the absence below the Skajit on John and Alatna rivers of the sandstone and shale series which underlies the Lisburne limestone on the John and Anaktuvuk. This absence may be accounted for by faulting, by nondeposition, or by the metamorphism of the sandstones and shales into the undifferentiated metamorphic schists. In view, however, of the absence of specific proof and the fact that other

¹ Schrader, F. C., op. cit., p. 87.

limestones are known in the stratigraphic column in northwestern Alaska it has seemed unwise at present to do more than suggest the possible equivalence of the Lisburne and Skajit formations.

The Skajit formation and the most extensive limestone on Alatna River are so nearly similar that no doubt is felt that the two are the same. Furthermore, there seems to be little room to doubt that the thinner band to the north on Alatna River is also the same limestone, having the same relation to the underlying schists. When traced westward, however, into the Noatak basin this same belt shows certain features that throw a little more light on the interrelations. It has already been noted that indistinct coral-like tubes, partly obliterated, that are found in creek gravels near the camp of July 30 are similar in general character to those found in the Carboniferous or Devonian limestones of parts of Seward Peninsula.¹ Furthermore, near the camp of August 1 (see Pl. X, *B*), these limestones overlies a series of sandstones that are indistinguishable from and are correlated with the Carboniferous sandstones to be described later. It is true that in this place the structure is exceedingly complex, and schistose rocks, sandstones, and limestones occur together in a confused manner. The sandstones, however, are perfectly distinct and do not seem to merge with the schists. They appear to be equivalent to the sandstones described by Schrader as immediately adjacent to the Lisburne limestone, and to the sandstones that will be described later as underlying the Carboniferous limestone in the western part of the Noatak basin.

Though the possible correlation of these limestones with those of Carboniferous age is thus emphasized, the fact must not be lost sight of that the evidence at hand is capable of other interpretations, and the uncertainty of the correlation suggested is so keenly felt that it has been deemed expedient to indicate the doubt by distinguishing on the map the known Lisburne limestone from these other rocks.

The age of the limestones of the Igichuk Hills is uncertain. No fossils have been found in them and their physical features do not distinguish them from several other thick limestone members in northern Alaska. Their outcrops where examined were so surrounded by deposits of recent alluvium that little of the general relations could be determined. Near the lower gorge of the Noatak, where Carboniferous rocks were exposed, there were some dolomites that suggested by their physical characters correlation with the Silurian dolomite of Seward Peninsula. Their close relation, however, with the Carboniferous rocks and the fact that dolomitic beds of considerable thickness occur in places in this series in Seward

¹ Smith, P. S., and Eakin, H. M., *op. cit.*, p. 48.

Peninsula renders this correlation doubtful. The limestone of the Igichuk Hills certainly appears to lie unconformably above schistose rocks which are similar in general aspect to those occurring on Alatna River and in the headwaters of the Noatak and which, from their lithologic character and topographic expression, appear to be equivalent to them.

In discussing the age of certain rocks of northeastern Seward Peninsula, Moffit¹ states that "the massive limestones mentioned above should probably be correlated with the Harris Creek and Baldy Mountain limestones." Kindle² subsequently determined that the limestones of Baldy Mountain and Harris Creek are Carboniferous, but owing to uncertainties of correlation and the different interpretations of the structure the suggested correlation should not be accepted without further investigation, for limestones of Ordovician, Silurian, and Carboniferous age occur in close proximity.

Of the limestones forming the small scattered areas in various parts of the Noatak-Kobuk region the only suggestion as to age is afforded by the limestones at the head of Dahl Creek, near Shungnak in the Kobuk basin. In the float in the central part of this valley, not far from an outcrop of a downfaulted block of limestone, indistinct corals were found in a limestone boulder. These were too poorly preserved to permit specific determination, but were of precisely the same appearance as fossils collected in 1909 from the limestones along the eastern flanks of the Darby Range in southeastern Seward Peninsula, which were identified as Devonian or Carboniferous.³ Another similarity between these limestones and those of Seward Peninsula is the strong petroliferous odor they emit when freshly broken. The limestones having these particular characteristics were dark, nearly black, with interlaminated bluish-white bands, the whole somewhat crystalline.

To sum up the question as to the age of the undifferentiated limestones, it is evident that, as is implied in their name, they may include several limestones of different ages. Although the evidence is not conclusive, there are reasons for believing that some are equivalent to the late Paleozoic limestones. It seems fairly certain that the limestones as a whole are younger than the undifferentiated metamorphic schists as a whole. Although by no means proved, it is believed that all of the undifferentiated limestones are of Paleozoic age.

¹ Moffit, F. H., *op. cit.*, p. 24.

² Kindle, E. M., Faunal succession in Port Clarence limestone, Alaska: *Am. Jour. Sci.*, 4th ser., vol. 32, 1911, pp. 335-349.

³ Smith, P. S., and Eakin, H. M., Geology of southeastern Seward Peninsula and the Nulato-Norton Bay region: *Bull. U. S. Geol. Survey* No. 440, 1911, p. 48.

SILURIAN SYSTEM.

The only rocks of known Silurian age were found by Kindle in the vicinity of Cape Deceit, a promontory near the town of Deering. The following account is taken from his description of this locality:

On the north coast of Seward Peninsula the writer has found at Cape Deceit a fauna which appears to be the same as the fauna at White Mountain [in the south-central part of the peninsula]. It is represented by a coral which is probably a species of *Amplexus* and a lamellibranch apparently identical with the *Megalodon* occurring at White Mountain. The limestone at Cape Deceit has the highly magnesian composition characterizing the limestone at White Mountain.¹

The limestone at White Mountain is described by Kindle in the same paper as being several hundred feet thick, of white to light-gray color, much broken by joints with very indistinct bedding planes, highly magnesian, and as containing a late Silurian fauna comparable with the Guelph in the States.

The fact that in every place where this formation has been found—in southeastern Alaska, on Porcupine River, in the Rampart region, and in Seward Peninsula—the rocks are dolomitic is believed to be significant. Although dolomites are known to occur in many other series, the fact that this part of the Silurian is everywhere dolomitic suggests that certain of the limestones in the Noatak-Kobuk region that have not yet been differentiated should be closely examined for this feature. Some of the dolomitic beds already noted in the region southeast of the canyon and in the lower gorge of the Noatak may possibly belong to the Silurian.

Unfortunately, the Silurian exposures at Cape Deceit are so isolated by the sea and by recent deposits of alluvium that they afford no clue as to their relations with the other rocks of the region. The fact that they are not schistose suggests that they are not so old as the undifferentiated metamorphic schists to the south, but even this conclusion rests on several unproved assumptions.

DEVONIAN SYSTEM.

Undoubted Devonian fossils have been found only in float boulders in John River basin a short distance north of Hunt Fork. The location of the rocks from which they were derived is therefore uncertain, though Schrader evidently believed that they were derived from the rocks exposed in the neighborhood. Owing to the fact that the particular outcrops from which the fossils came is not known, it has been impossible to indicate the Devonian strata on the geologic map (Pl. II), and they probably have been included in the Carboniferous rocks to be described later.

¹ Kindle, E. M., The faunal succession in the Port Clarence limestone, Alaska: *Am. Jour. Sci.*, 4th ser., vol. 22, 1911, pp. 347-348.

A reexamination of the original field notes fails to disclose a sufficiently explicit description of the rocks in the vicinity, and specimens brought back by Schrader afford the only means of determining the lithology and age of these rocks. From these specimens it may be seen that the rock is a sandy gray to dark-brown, medium fine grained, noncrystalline limestone, little if any cleaved, weathering to a lighter brown on exposed surface. The fossils are usually darker than the inclosing rock and show little or no evidence of deformation. These fossils were examined by Schuchert and Kindle, who report that they include *Spirifer disjunctus*, a typical Upper Devonian form.

In the Noatak region some doubtfully Devonian fossils have been obtained from rocks that were indistinguishable from the Carboniferous sandstones, shales, and limestones, and in this report these rocks have been included in the Carboniferous to be described later. That no marked break occurs between Upper Devonian and the lower Carboniferous (Mississippian) rocks in this part of Alaska is indicated by the facts that the truly Devonian rocks on John River were not distinguished by Schrader from the Carboniferous rocks, that the questionable Devonian rocks in the Noatak were not differentiated by the writer, and that Collier states that similar rocks in the Cape Lisburne region are apparently conformably overlain by lower Carboniferous rocks. It will therefore not be feasible to differentiate and map the two systems until more precise studies and more extensive collections have been made.

CARBONIFEROUS SYSTEM.

NOATAK SANDSTONE.

DISTRIBUTION AND LITHOLOGY.

Two main divisions of the Carboniferous rocks have been made, based mainly on differences in lithologic character. One division is composed mainly of sandstones, with subordinate amounts of quartzite, shale, and thin-bedded limestone; the other consists almost entirely of limestones. The former is called the Noatak sandstone, and the latter the Lisburne limestone, the geographic name given by Schrader.

The Noatak sandstone was seen and studied most extensively in the central and western parts of the Noatak basin, from the canyon as far east as the camp of August 9. Other areas correlated with this typical portion of the sandstone are the hills in which Midas Creek rises, north of the camp of August 2, and the northern part of the Rickett series mapped by Schrader on John River.

Views of characteristic phases of the Noatak sandstone and the topography to which these rocks give rise are shown in Plates V, A

(p. 29); XI, *A* and *B*; and XIV, *B* (p. 122). They illustrate the general field appearance of the rocks included in this formation.

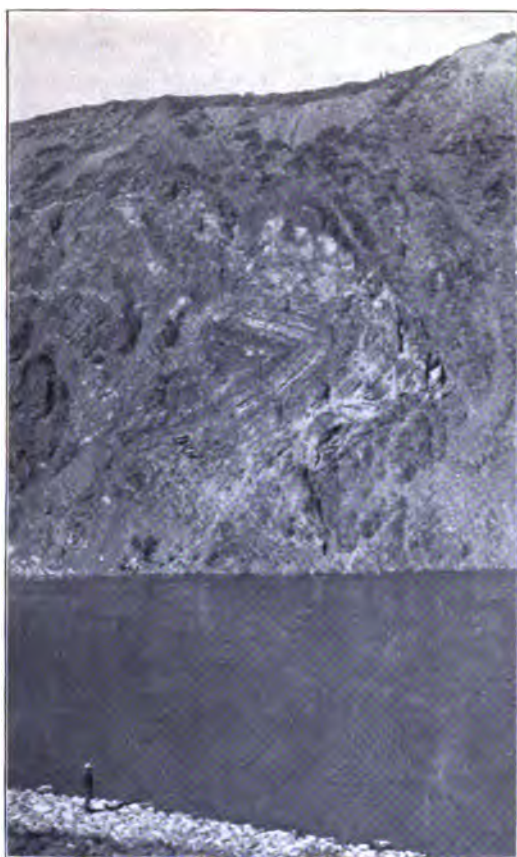
In the most typical exposures seen from a point near the camp of August 11 to the canyon the rocks are dominantly sandstones, medium fine grained and rather massive, but containing layers of shale that accentuate the bedding. On exposed surfaces the rocks are usually rusty brown to brownish green, but on fresh fracture they are dark gray or greenish. The component minerals are usually not distinguishable macroscopically with the exception of quartz and flakes of mica. When treated with acid many of the sandstones effervesce slightly, showing the presence of calcite. Under the microscope the sandstone is seen to be composed mainly of quartz and some sericite, with limonitic and carbonaceous material filling the interstices.

Some slightly conglomeratic beds are associated with the sandstones and certain of these show flattened masses of indurated shale or quartzite which are of pebble-like form, but which may represent contemporaneous accumulations of mud. Mica has been developed parallel with the surface of these nodules, but the material within is unshredded. Many of these accumulations closely simulate fossils and can be distinguished from them only by careful examination.

Some thin beds of limestone, few over a foot thick, are interbedded with the sandstones. These limestone beds show considerable variation in color, some being dark gray whereas others have weathered to a light yellow. All the limestones are semicrystalline, but exhibit only slight signs of movement. Fossils are fairly numerous in some of these beds and are entirely undeformed. In places the rocks are cut by small local calcite veins and have been intruded by basic intrusive rocks. The limestone beds become more prominent and thicker toward the top of the formation. Limestones may be recognized above the intrusive sill in the upper central part of Plate XI, *B*, and outside of the more closely appressed portion of the fold in Plate XI, *A*.

Shales and slaty beds are interlaminated with the other members of this formation. Generally they exhibit both bedding and cleavage, but not much metamorphism. The slates contain little clayey material but seem to be formed mainly of fine-grained quartz and some calcite. As a rule the rock is too fine grained to permit its component minerals to be distinguished. Under the microscope it is seen to be composed mainly of quartz, kaolin, or sericite, and a greenish, nearly amorphous, finely divided mineral, together with magnetite, some sulphides, and limonitic material.

Quartzites are especially common in the exposures in the vicinity of the Noatak Canyon. Most of them are dark, nearly black, but brown and red iron-stained members are not uncommon. The greater induration of the quartzites appears to be due to the pronounced folding to which the rocks have been subjected and also to the igneous



A. FOLDED PALEOZOIC ROCKS IN CANYON OF THE NOATAK.



B. PALEOZOIC ROCKS INTRUDED BY GABBRO, CANYON OF THE NOATAK.

intrusions in the vicinity. As a result of the igneous action much of their dark coloring matter has here and there been destroyed and they weather white, so that at a distance they are difficult to distinguish from certain of the limestones. This contact phase may in places be traced several hundred feet from the igneous rock. The red and brown colors noted above have been produced mainly by the weathering of sulphides that occur in the quartzites.

The rocks of the Midas Creek region that are provisionally correlated with the Noatak sandstone are typically sandy slates showing little or no schistosity, but having a well-marked lamination, which is in places transverse to the bedding. In addition to the quartz and scattered mica flakes observable in hand specimens, these rocks, when examined under the microscope, show a content of bleached biotite, chlorite, albite, zircon, and iron ores. The apparently greater shearing to which they have been subjected may be accounted for by their closer proximity to the region of pronounced dynamic metamorphism.

The rocks on John River that are correlated with the Noatak sandstone were described by Schrader, under the name Fickett series, as consisting of—

dark shale, schistose shale, and apparently some dark limestone, which is succeeded by quartzite, grit, and conglomerate * * *. The quartzite, grit, and conglomerate are hard and flinty, the grains and pebbles being thoroughly united by a siliceous cement. The best exposure of these rocks that was seen is that at Fork Peak [just north of latitude 68°], * * * from which point for about 15 miles northeastward to beyond the Anaktuvuk portage they present a steep face to the northwest * * *. Here the dip is gently south or southeast. Apparently these same conglomerates and grits were also encountered in the lower reaches of a deeply cut gulch about 20 miles south of Fork Peak, west of the mouth of Hunt Fork. Toward the top of Fork Peak the grit and quartzite give way to dark schistose slate and dark-gray micaceous sandstone.¹

According to Schrader's notes and descriptions, this same division includes metamorphic rocks which in the present report have not been correlated with the Noatak sandstone, but have been classed with the undifferentiated metamorphic schists. According to Schrader, these rocks overlie the more northern ones which have been correlated with the Noatak sandstone. Such an interpretation, however, presents so many difficulties that until further evidence is adduced it is believed more reasonable to accept the interpretation that the schistose beds are older than the less-deformed beds here correlated with the Noatak sandstone.

STRUCTURE.

In general the folding of the Noatak sandstone has not been so intense as that of the other rocks already described. Schrader reported open folding in this formation on John River. In the eastern

¹ Schrader, F. C., A reconnaissance in northern Alaska: Prof. Paper U. S. Geol. Survey No. 20, 1904, pp. 86-88.

part of the Noatak also the folding is not extreme, but vertical and overturned dips were observed at many places farther west. The folds and faults shown in Plates X, B, and XI, indicate that the structure is by no means simple. In spite of the complexity of local details the larger structure appears to trend in the main east and west. In a broad way the Noatak sandstone disappears under higher rocks toward the north and has been removed by erosion, it having been more uplifted, toward the south. Although this appears to be the general structure, it should be remembered that the actual structure is made up of subordinate folds and faults, which when viewed in detail present many diversities from this simple, locally inexact, generalization.

The Noatak sandstone has been subjected to pronounced regional dynamic metamorphism, and in addition to the larger structures cleavage has been produced in almost all its members except the more massive quartzite beds. This structure is particularly prominent in the finer-grained beds and in many places the original bedding is so masked that it may escape detection. Plate XIV, B (p. 122), shows an exposure of the slaty phase of the Noatak sandstone between the camps of August 12 and 13 on the north side of the Noatak. The bedding is shown by the color banding parallel with the hammer handle. This banding is evidently due not only to differences in color, but also to different chemical composition, texture, material, and size of grain. Transverse to the bedding and in Plate XIV, B, having a considerably lower dip is a well-marked cleavage, which is so strongly developed that the rocks weather into slabs parallel to its direction rather than to that of the bedding.

Although cleavage is everywhere noticeable, schistosity was not observed in the typical area of Noatak sandstone. In the area of rocks correlated with the Noatak sandstone on John River, however, Schrader mentions schistosity in certain members. It is possible that the rocks so described belong rather to the supposed underlying undifferentiated metamorphic schists than to the Noatak sandstone, and that they have been infolded or infaulted.

AGE AND INTERRELATIONS.

Fossils have been found at several places in the area of typical Noatak sandstone. The most definite collections from rocks in place were made at locality 11AS46, on the south side of the Noatak, about 8½ miles east of the camp of August 9, and at localities 11AS51 and 11AS53, on the north side of the river, about a mile east of the camp of August 11. Mr. Girty, who examined the fossils from these places, states that the three collections belong together, and he furnishes the following lists of fossil determinations:¹

¹ Girty, G. H., unpublished letter.

Locality 11AS46:

Menophyllum sp.
 Stenopora sp.
 Batostomella? sp.
 Schuchertella? sp.
 Chonetes aff. illinoisensis.
 Productus aff. indianensis.
 Productus aff. undatus.
 Productus aff. longispinus.
 Productella hirsutiformis?
 Camarotoechia sp.
 Spirifer aff. striatus.
 Spirifer aff. centronatus.
 Clithyridina aff. sublamellosa.
 Leptodesma aff. spergense.
 Aviculipecten sp.
 Bembexia? sp.
 Orthoceras sp.
 Paraparchites sp.

Locality 11AS51:

Zaphrentis sp.
 Lingula? sp.
 Schizophoria aff. swallowi.
 Chonetes aff. illinoisensis.
 Productus aff. indianensis.

Locality 11AS51—continued.

Productus aff. longispinus.
 Productus sp.
 Pugnax? n. sp.
 Dielasma aff. formosum.
 Spirifer aff. paucicostatus.
 Spirifer aff. striatus.
 Spiriferina aff. subelliptica.
 Ambocoelia aff. levicula.
 Clithyridina aff. hirsuta.
 Athyris? sp.
 Aviculipecten sp.
 Murchisonia sp.
 Pleurotomaria sp. 2.
 Euomphalus sp.
 Naticopsis n. sp.
 Naticopsis aff. carleyana.
 Paraparchites sp.
 Phillipsia sp.

Locality 11AS53:

Zaphrentis? sp.
 Chonetes aff. illinoisensis.
 Spirifer sp.
 Ambocoelia sp.

In discussing the significance of these determinations Mr. Girty says: "The geologic age I take to be upper Mississippian of the American section or the Mountain limestone or the *Productus giganteus* zone of the European section." On the first stream from the north, west of the camp of August 7, locality 11AS43, float boulders of limestone were found in great numbers in the stream gravels. Many of these contained fossils which Mr. Girty determined as follows:

Locality 11AS43:

Favosites? sp.
 Cladopora? sp.
 Cyathophyllum? sp.
 Stromatoporoid coral?

Locality 11AS43—Continued.

Zaphrentis.
 Crinoid stem.
 Camarotoechia? sp.

A short distance downstream from this place, on the south side of the Noatak the following fossils as determined by Mr. Girty were found in the float:

Locality 11AS45:

Zaphrentis sp.
 Cladopora? sp.
 Camarotoechia? sp.

From a bowlder of limestone in the canyon of the Noatak at locality 11AS67 a single fossil was found which Mr. Girty states is *Zaphrentis* sp.

Concerning these three collections Mr. Girty says:

The doubtful Carboniferous collections comprise lots 43 and 45 and possibly 67 * * *. The preservation of the specimens in these collections is very unfavorable and the forms themselves are not diagnostic. The faunas are unlike anything at present known in the Alaskan Carboniferous, and they appear to me to represent a pre-Carboniferous facies. Dr. Kindle, however, who kindly examined them at my request, writes me that he sees no good reason for calling them even provisionally Devonian. The reasons given for this opinion are the abundance of crinoid stems, some of which are said to have a peculiarly flattened form, and the fact that one of the corals (a rather slender small-celled branching form, which I have cited as *Cladopora*? sp., but which may possibly be of bryozoan nature) is a different species from a similar form in the lot which he is accepting as possibly Devonian.

It is evident, therefore, that a satisfactory determination of the age of this fauna must be deferred until it is possible to obtain more diagnostic and more satisfactorily preserved material.

In the John River region Schrader found no fossils in place, but numerous stream pebbles in the regions where the rocks now referred to the Noatak sandstone outcrop yielded lower Carboniferous (Mississippian) forms, as determined by Prof. Charles Schuchert. The lithology of the pebbles was similar to that of the rocks in place, but it is possible that some of the fossils may have come from the Lisburne limestone farther upstream to the north. The following identifications were made by Prof. Schuchert:

Locality 493:

Lithostrotion (of the group in which the corallites are not in close embrace).

Locality 495:

Spirifer striatus Martin.
Productus scabriculus Martin.
Spirifer near *S. neglectus* Hall.

Locality 513:

Productus scabriculus Martin.

Locality 520:

Productus semireticulatus Martin.

Locality 521:

Spirifer striatus Martin.
Productus, a very small undetermined species.
Cystodictya nearest to *C. lineata*.

Locality 522:

Spirifer striatus Martin.
Fenestella.

Locality 525:

Spirifer striatus Martin.
Spiriferina cristata Schlotheim?

Locality 534:

Streblotrypa near *nicklesi* Vine.
Fenestella, several species, one of which is near *F. cestriensis* Ulrich.
Cystodictya.
Pinnatopora.
Rhombopora.

The above eight localities represent one formation in the upper part of the Lower Carboniferous. This fauna is unlike that of the Mississippi Valley in that it does not have the characterizing fossils, as the screwlike bryozoan *Archimedes* and the blastoid genus *Pentremites*.

Localities 497 and 529 have a *Syringopora* much like *S. multattenuata* of the Upper Carboniferous. This genus, however, has little stratigraphic value, but the development of the species present is indicative of Carboniferous.

Localities 511, 518, and 454 are represented by a crinoidal limestone apparently the same as at localities 525 and 521 and probably from the horizon of the latter.

Localities 463 and 464 represent another horizon, since the lithology is quite different from any of the other localities. The only fossils present are large crinoidal columns like those of the Lower Carboniferous.

Locality 461 also has large crinoid columns and may represent the Lower Carboniferous.

The above localities probably all represent the same Lower Carboniferous formation as that of the specimens from localities 493, 495, 513, 520, 521, 522, 525, and 534.

Locality 519 has *Fenestella*, *Cystodictya*?, and crinoid columns. The material is unsatisfactory, and all I can do is to state that it indicates either Devonian or Carboniferous.¹

From the above facts it is concluded that the Noatak sandstone is of lower Carboniferous (Mississippian) age. Possibly certain of the lower beds may have been formed in the extreme upper part of the Upper Devonian, but from Kindle's statement (p. 74) there is considerable reason for believing that all the rocks are Mississippian.

LISBURNE LIMESTONE.

DISTRIBUTION AND LITHOLOGY.

The name "Lisburne" was first applied by Schrader to the limestones at Cape Lisburne and was extended to include similar limestones found by him at the head of John and Anaktuvuk rivers. Later studies of the type locality were made by Collier² and still more recently by Kindle,³ but this area is outside the region treated in this report. As a result of the work of the expedition of 1911 certain limestones in the western part of the Noatak region have been assigned to this formation. The position of the different areas is indicated on the geologic map (Pl. II), and the Noatak and John-Anaktuvuk localities will be described in the following pages.

On John River the Lisburne limestone forms a belt about 15 miles wide. According to Schrader:⁴

The rocks of the Lisburne formation may be characterized for the most part as medium-bedded semicrystalline limestones of impure white or gray color. They weather gray, light rusty brown, or chocolate. They form the mountains that rise to a height of 2,500 to 3,000 feet above the floor of the Anaktuvuk Valley. Near the summit occur two beds of intercalated shale, each apparently several hundred feet thick and containing some thin layers of dark gray limestone * * *. Judging from exposures observed in the region of the Anaktuvuk, the thickness of the limestone formation is probably a little over 3,000 feet.

In the Noatak region three areas are correlated with the Lisburne—one southeast of the canyon, one in the hills west of Kuguruk River, and one in the lower gorge of the Noatak. The first is about 5 miles southeast of the camp of August 14, in a region of considerable faulting and igneous intrusion, where the relations are complex. The rocks exposed here are highly siliceous cherty limestones, considerably brecciated and recemented by chert. They are light brown

¹ Schrader, F. C., op. cit., p. 70.

² Collier, A. J., *Geology and coal resources of the Cape Lisburne region, Alaska*: Bull. U. S. Geol. Survey No. 273, 1906.

³ Kindle, E. M., *The section at Cape Thompson, Alaska*: Am. Jour. Sci., 4th ser., vol. 28, 1906, pp. 520-528.

⁴ Schrader, F. C., op. cit., p. 63.

on exposed surfaces, but on fresh fracture are in places much darker. Indistinct fossils, mainly crinoid stems replaced by silica, may here and there be found on the weathered surfaces. Farther north these limestones are apparently overlain by a band of nearly black semicrystalline limestone with numerous white patches formed by the remains of corals. The rocks are exposed in small outcrops on steep north-facing scarps.

West of the Kugururok, limestones form the hills bounding the Mission lowland to the north. At a distance most of the hills are a brilliant white, but west of Kelly River a steep ravine exposes reddish limestones underlying the white. The rocks were not examined in place, but float from these hills showed the light-colored limestone to be semicrystalline and to have numerous thin dark, nearly black bands interlaminated with bluish-gray to white beds. Pebbles of the reddish limestone were similar to those found farther east, near the camp of August 4, and to the reddish sandy limestone that occurs near the base of the undifferentiated limestones around the head of the Noatak, north of the camp of July 28. On microscopic examination the red color was found to be due to a considerable amount of hematite in the rock. This coloring material is not evenly distributed but is concentrated irregularly here and there. It may have been leached from a calcareous sediment rich in iron. This reddish-brown limestone is also considerably exposed in the hills at the head of Cosmos Creek north of Shungnak, in the Kobuk region, and is there included in the undifferentiated limestones.

In the lower gorge of the Noatak, about half a mile below the camp of August 25, there is a silicified limestone bearing some indistinct fossils on its weathered surface. Boulders of a dark, nearly black limestone containing numerous well-preserved fossils in such position that they evidently had not traveled far were found near the upstream end of this exposure. A little farther downstream is an outcrop of a brecciated dolomite, which is not distinguished from the other limestones. Indistinct unidentifiable organic remains were found in this dolomite. Still farther downstream, near the western limit of the exposures, is a dark, nearly black semicrystalline limestone with thin light-colored partings, which are so numerous that over 30 were counted in a thickness of an inch of limestone. This phase is nondolomitic.

STRUCTURE.

The rocks correlated with the Lisburne limestone show no structure discordant with that of the Noatak sandstone, already described. In all exposures the rocks are considerably folded and show secondary structures induced by the regional metamorphism. In the locality near the canyon and in the area west of the Kugururok the general

trend of the lines of major structure is east-west to northwest-southeast, and the dip is dominantly toward the north. In the exposures near the lower gorge the strike appears to be about N. 20° W. and the dip steep and variable from west to east.

Smaller structural features, such as jointing and cleavage, are often seen and have caused the rocks to weather in slabby form. The intersection of the folding by the jointing in places gives rise to a "pencil structure," by forming fragments 6 to 8 inches long and half an inch thick. Brecciation also occurs in certain members of this formation, especially the dolomite, the cement being considerably more crystalline than the older fragments.

AGE AND INTERRELATIONS.

Fossils from the limestones southeast of the canyon have been examined by Messrs. Girty and Kindle. The former furnishes the following list of fossils from the more southern beds:

Locality 11AS65:

Bryozoan?

Productus? sp.

| Locality 11AS65—Continued.

Spirifer aff. rockymontanus.

Composita aff. subtilita.

Concerning this collection Mr. Girty states that it contains little that is distinctive, so that nothing definite can be said regarding it, although it is rather suggestive of the Pennsylvanian.

Mr. Kindle examined the fossils from the more northern locality and writes:¹

The material consists entirely of fragmentary corals embedded in a dark dolomitic limestone. The best preserved and most abundant of these is a species of *Cladopora*, which is comparable with *C. labiosa*. Both the fossils and the rock matrix resemble rather strongly some of the specimens that have been obtained by me and by others from Black Mountain, in Seward Peninsula. The evidence is insufficient to make any positive correlation, but I would suggest that the material might be assigned provisionally to the Devonian, unless there is some distinctive stratigraphic evidence against such an assignment. The fossils probably represent either Devonian or Mississippian, probably the former.

Float fossils found near this place in the Noatak canyon and also on a gravel bar near the camp of August 19, probably derived from the limestones of the hills to the north, have been examined by Mr. Girty, who identifies the specimen from the former locality (11AS61) as *Lithostrotion portlocki?* and that from the latter (11AS73) as *Lithostrotion irregulare?* Mr. Girty states in a letter accompanying these determinations:

These I believe to belong at about the same horizon as the foregoing [Nos. 46, 51, and 53, from the Noatak sandstone], showing merely different aspects of the same fauna. These coral lots (Nos. 61 and 73) have the facies that we know in the Lisburne limestone, which I believe to be composed of equivalent beds.

¹ Kindle, E. M., unpublished letter.

The richest fauna was obtained from the dark, nearly black limestone float at the northern part of the lower gorge of the Noatak. The following fossils were determined by Mr. Girty:

Locality 11AS77:

Fenestella, several sp.
Pinnatopora sp.
Batostomella? sp.
Cystodictya sp.
Rhipidomella aff. *pulchella*.
Derbya sp.
Chonetes aff. *illinoisensis*.
Productus aff. *undatus*.
Productus aff. *indianensis*.
Productus aff. *semireticulatus*.
Productus aff. *longispinus*.
Productus aff. 2 sp.
Dielasma sp.
Spirifer aff. *striatus*.
Spirifer aff. *paucicostatus*.
Martinia aff. *glabra*.
Reticularia sp.
Cliothyridina aff. *hirsuta*.
Nucula sp.
Leda sp.
Palæoneilo aff. *sara*.
Edmondia sp.

Locality 11AS77—Continued.

Leptodesma aff. *spergenense*.
Aviculipecten sp.
Sphenotus aff. *contractus*.
Sphenotus aff. *unioniformis*.
Sphenotus sp.
Sanguinolites sp.
Schizodus sp.
Schizodus? sp.
Cypricardina? sp.
Pleurotomaria sp.
Platyceras sp.
Naticopsis sp.
Euomphalus aff. *spergenensis*.
Sphærodoma aff. *littonana*.
Bulimorpha sp.
Loxonema sp.
Trochus? sp.
Orthoceras sp.
Eumorphoceras? sp.
Paraparchites sp.
Glyptopleura sp.
Primitia sp.

According to Mr. Girty these fossils belong to the same group of rocks as those found in the Noatak sandstone and already described (11AS-46, 11AS51, and 11AS53). As stated above, however, he is of opinion that these rocks lie at about the same horizon as the Lisburne limestone, but they show different aspects of the same fauna. In one the fossils are mainly corals, whereas in the other they are principally mollusks.

Although the paleontologic evidence from the only rocks of this formation that were found in place is not so conclusive as is desired, there seems to be no valid objection to considering all of these limestones as one formation of Mississippian age. According to Mr. Girty's determination, based on the fossils from localities 11AS46, 11AS51, and 11AS53, the Noatak sandstone and this limestone formation are of practically the same age.

Further detailed studies will undoubtedly separate this formation into different members, but the present statements serve to bring out the early Carboniferous age of these rocks and to suggest their correlation with the Bettles "series" of the Koyukuk and Chandalar regions (described by Schrader) with certain limestones of Seward Peninsula and with similar limestones in the Yukon-Tanana region.

MESOZOIC ERA.

DIVISIONS OF THE ROCKS.

Three areas of Mesozoic rocks are shown on the geologic map (Pl. II). The largest of these areas forms the southeastern part of the region shown on the map and embraces most of the basin of the main Koyukuk River. Two smaller areas of Mesozoic rocks are shown in the extreme northern part of the mapped area. These areas are probably only a small part of the actual exposures of these rocks, for the region is practically unexplored. So far as known the rocks in all three of these areas are of Cretaceous age. Owing, however, to differences in age and lithologic character they have been divided into three groups: On the south side of the Endicott Mountains two groups, the Koyukuk and Bergman, have been distinguished and have been differentiated from the Cretaceous rocks north of the range. This separation does not imply that a part of the group north of the mountains may not be the equivalent of certain of the rocks to the south. In addition to the Mesozoic rocks found and mapped Triassic float was noted in the central part of the Noatak basin.

TRIASSIC SYSTEM.

OCCURRENCE.

Triassic rocks have been recognized in the region treated in this report only as float in the central part of the Noatak basin, in the gravels of the first stream from the south below the camp of August 7. The material is practically indistinguishable in lithologic character from the dark Carboniferous limestones in the vicinity. At the time the rock was found its significance was not appreciated and a thorough examination of the neighborhood was not made. Triassic fossils were obtained from a piece of float of nearly black chert within dark thin-bedded limestone. The silicification had taken place subsequent to the consolidation of the rock and had replaced much of the original material, which was probably limestone. The fragment was very hard, so that it may have been carried for a long distance, but in the field the impression was that the rock had not traveled far. Float limestone, questionably of Devonian but certainly of Paleozoic age, was also found in the same stream gravels, so that little or nothing of significance concerning the areal distribution of the Triassic rocks from which the float was derived could be determined without extensive investigation.

AGE AND CORRELATION.

The age of the fossiliferous cherty limestone float was determined by Mr. Stanton, who states:

7244. No. 11AS44; Noatak River at first stream from south, west of the camp of August 8, approximately latitude 68° N., longitude 159° W.:

Pseudomonotis subcircularis (Gabb).

Upper Triassic. The collection contains only a single species, but it is represented by a number of well-preserved specimens and is a widely distributed and very characteristic form found thus far only in the Upper Triassic.

This is the same horizon as that represented at Cape Thompson, 175 miles to the west, where Kindle¹ found dark cherts and thin-bedded cherty Upper Triassic limestones overlying Carboniferous rocks and interbedded with soft black shales and argillites containing black, green, and dull-red cherts. It should be noted that there was a considerable interval between the known Carboniferous and Upper Triassic. So far as now known this period in northwestern Alaska was unattended by deposition and its history is consequently obscure.

Although Triassic rocks have been reported only at the above two localities in northwestern Alaska the same characteristic fossils have been found at many places elsewhere in Alaska. They have been found along the Alaska-Yukon boundary, in the central part of southeastern Alaska, in the Copper River region, and in southwestern Alaska. The rocks are therefore widespread, and it is highly probable that with further study some of the areas in northwestern Alaska composed dominantly of older rocks may prove to have infolded and unfaulted representatives of this younger system.

LOWER CRETACEOUS OR UPPER JURASSIC SERIES.

KOYUKUK GROUP.

Distribution.—The Lower Cretaceous or Upper Jurassic rocks represented on the geologic map (Pl. II) have been found in the central part of the Koyukuk basin and on the northern face of the Endicott Mountains. These rocks in the Koyukuk basin have been called by Schrader² the Koyukuk series, a name that has been applied also to the lithologically similar rocks of the Zane Hills.

Lithologic character.—Schrader describes the typical formation as an impure pinkish to reddish-colored limestone, which is associated with igneous amygdaloids and andesitic tuffs.³ In his later report he noted that in addition to these rocks he found dark shale, slates, and some sandstones or arkose. The area studied by Schrader was near

¹ Kindle, E. M., Section at Cape Thompson, Alaska: *Am. Jour. Sci.*, 4th ser., vol. 28, 1909, pp. 526-528.

² Schrader, F. C., Preliminary report on a reconnaissance along the Chandalar and Koyukuk rivers, Alaska, in 1899: Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 2, 1900, pp. 476-477; A reconnaissance in northern Alaska: Prof. Paper U. S. Geol. Survey No. 20, 1904, p. 77.

³ Schrader, F. C., Preliminary report on a reconnaissance along the Chandalar and Koyukuk rivers, Alaska, in 1899: Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 2, 1900, p. 477.

the northeastern boundary of these rocks, where the dip was in general northeast. He reported that the limestone member is 800 feet thick.

In the Zane Hills, where similar rocks were examined by the Survey party in 1910, limestones were entirely absent and the group consisted of agglomeratic and arkosic beds associated with basic intrusives and effusives cut by acidic intrusives. This area was near the western margin of this group, where the strikes are dominantly northwest to southeast and the dips are westward. Characteristically the rocks are dark colored, generally greenish, but here and there dark red. As they are arkosic rocks, it is very difficult in the field to differentiate their sedimentary and igneous phases, so that the two have been mapped together. Some conglomeratic beds were recognized, but the pebbles were mainly of dark igneous rocks, none formed of schists or granites having been recognized. Ferromagnesian minerals are common and appear as glittering crystal faces on freshly broken specimens. Generally, however, the rocks are too fine grained to permit macroscopic determination of their component minerals.

The rocks are thoroughly indurated and compact, even on exposed surfaces, where they are firm and solid or but little disintegrated. So well are the various components consolidated that the rock breaks across the grains rather than around them. No great differences in resistance to erosion were noted between the different members, and consequently no notable features have been produced by erosion. Steep cliffs have been formed at many places, but they do not persist for long distances nor mark easily identifiable horizons, being rather the expression of various erosive activities working on essentially homogeneous material.

Fragments of vein quartz were not recognized in the Koyukuk group and later formed veins were not seen in the Zane Hills, though they are noted by Allen and Schrader in similar rocks farther east. No mineralization was seen and the group is believed to be practically barren.

Structure.—The major structure of the Koyukuk group where it is exposed is anticlinal. The trend of the axis is broadly northwest-southeast; the dips are to the east on the eastern margin and to the west on the other side. However, there has been much minor deformation, so that the structure is by no means simple. Faults of considerable magnitude have been observed and more profound movements must be postulated in order to explain the observed facts of distribution. As a result of these movements slickensiding has been produced and in a few places schistosity has been developed. It is believed that this schistosity, however, is distinctly local and is entirely separated from the schistosity noted in connection with the undifferentiated metamorphic rocks. (See pp. 55-60.)

The deformation to which the group has been subjected has produced cleavage and jointing. Schrader¹ notes that "A profuse jointing trends N. 25° W. and dips steeply northeast, and a well-marked cleavage strikes northeast and dips 75° SE." In the Zane Hills no such persistency in direction was observed, though the structures were evident. Owing to the complex structure the thickness of the group was not determined, but it is evidently great.

Near the granitic contacts the Koyukuk group is in many places considerably indurated and new minor structural features have been produced. It must not be inferred, however, that the rocks have been recrystallized, for they have not; though the induration is greater and the texture is more compact few new minerals have been developed.

Age.—The age of the Koyukuk group has been determined by means of fossils collected by Schrader from the pink limestone on the west bank of the Koyukuk near Waite Island and from another locality a few miles farther downstream to the southwest. Both collections were determined by Stanton,¹ who reports that they contain *Aucella crassicollis* Keyserling, a fossil characteristic of the Lower Cretaceous in Russia, though other species of *Aucella* are found in the Upper Jurassic. No other fossils have been found in this group of rocks and it is therefore evident that the age of the portions other than the limestone is extremely doubtful.

The age limits of this group can not be fixed definitely, but certain facts indicate that although some parts of it may have a more extended range the group as a whole was formed during Lower Cretaceous time. The facts that elsewhere in Alaska there was a considerable diastrophic break between the Upper and Lower Cretaceous, that Upper Cretaceous is represented in the region and lies unconformably above the Koyukuk, that this group is cut by granites similar to the granites represented by pebbles in the Upper Cretaceous beds, all point to the conclusion that these beds do not extend above the Lower Cretaceous. On the other hand, although none of the older Mesozoic rocks are known to be represented in the region, the difference in lithology suggests that the Koyukuk group does not belong to either the Jurassic or Triassic.

ANAKTUVUK GROUP.

Lithologic character.—The Anaktuvuk group of Lower Cretaceous or Upper Jurassic rocks has been examined only by Schrader, from whose report² the following statements are practically quoted.

The group consists of impure sandstone or arkose and a little conglomerate. The sandstone is usually heavy bedded, beds 6 to 8

¹ Schrader, F. C., A reconnaissance in northern Alaska: Prof. Paper U. S. Geol. Survey No. 20, 1904, p. 77.

² Idem, p. 75.

feet in thickness being common, and is generally fine to medium grained, but in some localities becomes so coarse as to be almost a grit. In color it ranges from dark or bluish gray to dirty green. The coarser grained rock commonly presents a speckled appearance and seems to be composed of grains of variously colored flint. Although distinctly sedimentary in origin, it contains also some detritus of igneous rocks, such as fragments of feldspar and ferromagnesian minerals. The igneous rocks from which these sediments were derived were not observed in the vicinity of the Anaktuvuk. Conglomerate is apparently rare, having been observed at only one place. Here it is typically rather fine, few pebbles being more than three-fourths inch in diameter. The pebbles are noted for their angularity and consist mainly of white quartz and dark slate-colored flint. The cementation is firm, but is not so strong as that of the Paleozoic rocks to the south.

Rocks reported by Howard on the Colville have been provisionally correlated with the Anaktuvuk group. Practically nothing is known about these rocks except for reports of prospectors that the sandstones contain coal beds and the statement by Howard¹ that at this place outcroppings of coal were observed. Inasmuch as coal is not known in the typical Anaktuvuk localities considerable doubt is felt as to the validity of this correlation.

No accurate measurement of the thickness of the Anaktuvuk group was made by Schrader, but he estimates it to be at least 2,000 feet.

Structure.—The general strike of the Anaktuvuk rocks is east and west and the major structure is monoclinical. The rocks in general dip gently northward at varying angles but present subordinate low anticlines and synclines. The structure was probably produced by the same mountain-building forces that were exerted in the range to the south. Beside east-west flexures the rocks exhibit a subordinate or minor system of cross folds or warpings, whose axes trend north and south, giving rise here and there to low domes.

The group is freely traversed by two systems of jointing. The dominant or major system trends nearly northwest and dips almost vertically to the southwest. The minor system traverses the rocks at nearly right angles to the major and trends northeastward, dipping southeastward at an angle of about 80°. Both systems seem roughly to correspond in trend with the similar structure in the Paleozoic rocks in the Endicott Mountains.

Age.—The age of the Anaktuvuk group was determined by Stanton as probably Lower Cretaceous by means of fossils collected by Schrader about 8 miles north of the margin of the Endicott Mountains and at several points still farther north. Of these fossils the most characteristic are *Aucella crassicollis* Keyserling and closely related

¹ Stoney, G. M., Naval explorations in Alaska, Annapolis, 1900, p. 69.

forms which indicate Lower Cretaceous age, though it is possible that they may come from the uppermost Jurassic. Schrader, however, points out that no fossils were obtained near the base of the group and consequently the lower age limit is not proved. The general uniformity of lithologic character throughout the group suggests that there is no decided break in the sequence of the beds and that as regards period of formation the group is probably a unit.

On paleontologic grounds the Anaktuvuk group may be directly correlated with the Koyukuk group, which occurs on the south side of the mountains. Lithologically, however, the two are entirely dissimilar, for although contemporaneous igneous rocks are numerous in the southern area they are entirely absent in the region north of the range.

UPPER CRETACEOUS SERIES.

BERGMAN GROUP.

Distribution.—Upper Cretaceous rocks occur extensively in the Koyukuk basin and also south of the Kobuk. These rocks were first recognized by Schrader in 1899,¹ but were not adequately described until after Mendenhall's and Schrader's expeditions in 1901. Mendenhall's results were published about two years earlier than Schrader's, but the field work on which the reports were based was practically contemporaneous. The name Bergman is derived from a formerly important trading post on the Koyukuk below Alatna River.

Lithologic character.—Dominantly, the Bergman group is a series of dark greenish-gray arkosic conglomerates and sandstones. The base of the section exposed on Alatna River, on the lower part of John River, and on the upper part of the Kobuk is a conglomerate made up of pebbles of the older rocks, namely schists, limestones, vein quartz, and igneous rocks, such as greenstones and granites. The beds are thoroughly indurated and are usually more resistant than the higher sandstones. As a result, they form conspicuous pinnaced ridges, particularly in the range north of the Kobuk from Beaver River westward to the Mauneluk. It is because of similarity in topographic expression in this particular that the hills south of the Kobuk from Ambler River westward are correlated with the areas of Upper Cretaceous rocks. This division corresponds closely in all physical features with the Ungalik conglomerate, of probable Upper Cretaceous age, described in the extreme eastern part of Seward Peninsula and the adjacent Norton Bay region.²

Toward the top of the lower division sandstones become more numerous, and at its top the group is composed almost entirely of

¹ Schrader, F. C., op. cit., p. 77.

² Smith, P. S., and Eakin, H. M., A geologic reconnaissance in southeastern Seward Peninsula and the Norton Bay-Nulato region, Alaska: Bull. U. S. Geol. Survey No. 449, 1911, pp. 55-57.

sandstones which are practically indistinguishable from the sandstones of the Shaktolik group of the more southern part of the Koyukuk basin.¹ The rock is medium fine grained, of rather uniform texture, and generally of a greenish-gray color. It is thoroughly indurated and offers fair resistance to weathering, not so great resistance, however, as most of the rocks already described. As a result, the sandstone portion of the Bergman group generally forms somewhat rounded, coarsely dissected hills of medium elevation.

The rock contains abundant fragments of rather angular ferromagnesian minerals and feldspars, whose glittering faces and partial crystal outline resemble the phenocrysts of an igneous rock. Generally, the beds are rather massive, showing no pronounced stratification. At many places, however, beds of dark shale interlaminated with the sandstones serve to bring out the structure. No extensive exposures of the shales were observed by the expeditions of 1910 or 1911, but Mendenhall² notes belts of shale many hundred feet thick. He also notes red and green shales in the Kobuk basin near Lake Nuvavukti, but such shales have not been recognized in other parts of the region.

Fragments of what appears to be wood and lignitic beds have been found here and there in the sandstone member. A bed of lignite occurs in the hills immediately east of Pah River, and another near Tramway Bar on the North Fork of the Koyukuk, but both beds are apparently thin and of poor quality. Owing to the absence of determinative fossils some areas in the central part of the Kobuk basin mapped provisionally as Tertiary may prove to be Upper Cretaceous, in which case workable lignite beds may on closer examination be found in the Bergman group.

Structure.—The Bergman group as a whole is considerably folded and faulted, and the average inclination of the beds is probably about 45°. Along the northern margin of the area occupied by these rocks the strike is approximately east-west and the dip south, but even in localities so near the northern margin as the Lockwood Hills the dip is in places northward. The group has therefore been thrown into a number of appressed but not overturned folds. This deformation was accompanied by faulting but, so far as determined, by no profound dislocation, and the faults appear to have been of the normal or gravitative type. The Bergman group appears to have been less severely deformed than the Koyukuk group in the same region, and this appearance was also noted by Schrader,³ who states: "On the whole the series does not seem to have received from the

¹ Smith, F. S., and Eakin, H. M., *op. cit.*, pp. 57-60.

² Mendenhall, W. C., *Reconnaissance from Fort Hamlin to Kotzebue Sound, Alaska*: Prof. Paper U. S. Geol. Survey No. 10, 1902, p. 39.

³ Schrader, F. C., *op. cit.*, p. 78.

of muscovite and foils of chlorite. These beds have a distinct brown color by which at a distance they may be distinguished from the other rocks.

About 25 miles west of the locality on Ambler River and just below the mouth of Hunt River there is an outcrop of a hard quartz conglomerate containing coal fragments, and prospectors report that similar beds form bluffs for several miles along the lower course of Hunt River. In the banks of the Kobuk 30 miles still farther west are the most extensive exposures of these rocks. For 8 to 10 miles below the mouth of Reed River a succession of conglomerate layers, with pebbles of quartz, mica schist, limestone, and serpentine embedded in a micaceous matrix alternating with less resistant beds, is in places exposed in both banks of the Kobuk. The individual conglomerate beds vary from 10 to 200 feet in thickness, but are of rather uniform character. The softer beds between are sandstones, shales, fire clays, and coals. The coals in these rocks are described on pages 151-152.

STRUCTURE.

According to Mendenhall the Tertiary rocks of the Kobuk basin are everywhere thrown into folds. Faults, however, were not observed. The structure is decidedly complex and is distinctly local, but time was not available for examining the exposures, so that the structural details can not be stated. Owing to the fact that the structure was not completely worked out the thickness of the Tertiary rocks was not determined.

AGE AND INTERRELATIONS.

The age of the Tertiary beds of the Kobuk region was first determined by Dall,¹ whose decision was based on specimens and descriptions furnished by Cantwell, without fossils. However, apparently from the fact that these beds were similar to and on the strike of fossiliferous beds of supposed Tertiary age to the southeast, near Nulato, Dall says: "There can be little, if any, doubt that they belong to the same series." Subsequently, during the explorations by Mendenhall, fossils were obtained from the sandstones near the mouth of Reed River. These were examined by Knowlton,² who reported:

This collection consists of five small specimens, the matrix being grayish, fine-grained, very hard sandstone. The plant remains are not retained with great fidelity, but fortunately all are determinable. Four species are represented, as follows: *Ginkgo* sp., probably *G. adiantoides* (Unger) Heer, *Taxodium distichum miocenum*, Heer, *Taxodium tinajorum* Heer, *Populus arctica* Heer. With so few species as a basis

¹ Dall, W. H., and Harris, G. D., Correlation papers, Neocene: Bull. U. S. Geol. Survey No. 84, 1892, pp. 248-249.

² Mendenhall, W. C., Reconnaissance from Fort Hamlin to Kotzebue Sound, Alaska: Prof. Paper U. S. Geol. Survey No. 10, 1902, p. 42.

for comparison it is not possible to speak very dogmatically as to their probable age, but, all things considered, I should incline to refer them to the so-called Arctic Miocene, which is now generally regarded as belonging really to the Upper Eocene.

The Eocene age of the fossils seems fairly well established, but the question previously raised (see p. 87), whether or not there was unbroken deposition from the Upper Cretaceous into the Eocene, so that the two merge uninterruptedly, should be considered. The similar areal distribution of the two series, their similar lithology, and the apparently identical diastrophic history to which both have been subjected, all point to the conclusion that there was no stratigraphic break between the Mesozoic and the Tertiary. According to this interpretation the Eocene beds of the Kobuk basin mark deposits formed close inshore or in part on the land at a late period in a cycle of constantly encroaching marine invasion which commenced in the Upper Cretaceous and was terminated by mountain building at the close of the Eocene. In other words, the conglomerate deposited close to the old land during this cycle of submergence is regarded as forming an unbroken lithologic unit which ranges in age from Eocene to Upper Cretaceous.

QUATERNARY SYSTEM.

DIVISIONS OF THE DEPOSITS.

A great many deposits of Quaternary age have been recognized in the Noatak-Kobuk region. These beds have been formed under many different conditions during a considerable period of time; and may be divided into three distinct types, namely, marine, stream, and glacial deposits. Some of these deposits belong to one or the other of the above types, but in the main the various processes have so interacted that the result has been deposits having features characteristic of several agencies. Although an attempt will be made to distinguish the various agencies involved in the formation of the different deposits, the subdivisions used in mapping and in the following descriptions are based on time of formation rather than on mode of genesis. Only two divisions have therefore been made of the Quaternary deposits shown on the geologic map (Pl. II), namely, the recent deposits and the older bench or high-level gravel deposits. In many places it has been impossible to draw a hard and fast line between the two divisions, not only because of the lack of specific information but to a great extent because the scale of the map is not large enough to permit the facts to be represented without enormous exaggeration. To emphasize the limitations imposed by the scale it may be pointed out that a deposit 100 yards wide in the field would be represented on the map by a line about 0.007 of an inch thick. Consequently the Quaternary deposits, especially the recent gravels, have been omitted from all the smaller streams.

OLDER DEPOSITS.

DISTRIBUTION.

The older gravels occupy much more extensive areas than the recent deposits described on pages 104-106. They spread over much of the region and give the dominant features to the topography near the main rivers. Their origin is complex, and although they have been studied at many places, not enough is known of the entire region to allow an adequate treatment of their distribution and interrelation.

In the Noatak region these older gravel deposits are most abundant between the coast and the Igichuk Hills, in the Mission lowland, and in the Aniuk lowland, but small remnants here and there on the hillsides above the present streams in many parts of the basin point to a much wider distribution of these deposits in the past. In the Kobuk basin extensive deposits occur near the mouth of the river, and from Squirrel River eastward to a point beyond Reed River. Here, also, a much wider distribution is indicated for these deposits in the past. In the part of the Koyukuk basin treated in this report there are enormous areas of old gravel deposits. Along the main river the largest areas of these deposits occur southwest of the Zane Hills, south of the Alashuk and south and east of the mouth of the Alatna. On the tributaries of the Koyukuk large areas occur in the basin of the Hogatza, in the lower part of the Alatna, and in the vicinity of Siruk Creek, possibly joining with the Hogatza flats, and in the lower part of John River. On all the streams, however, there are higher smaller deposits that are apparently portions of more extensive deposits which have been partly removed by erosion. All these areas of older Quaternary deposits are indicated on the geologic map (Pl. II), which best illustrates their distribution.

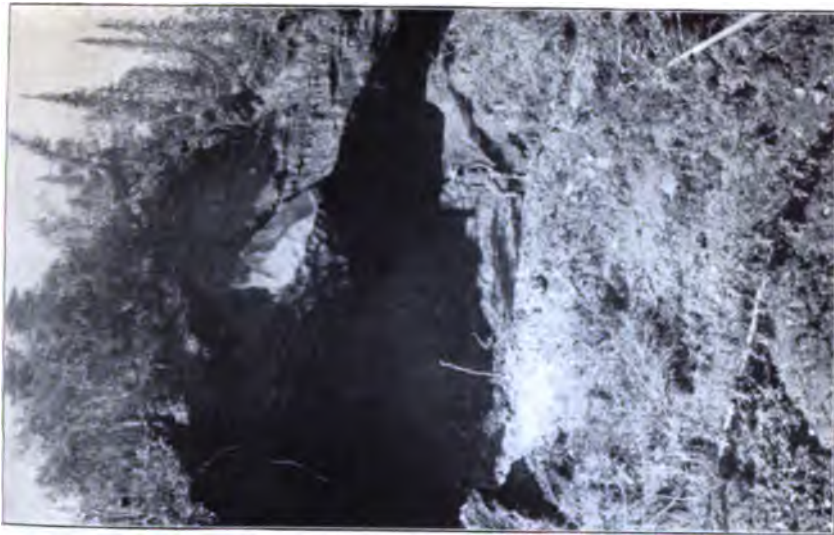
PHYSICAL FEATURES.

Noatak basin.—Certain of the older deposits were evidently formed by a single process, but most of them were produced by various activities, so that it is difficult to classify the several deposits by genesis, and therefore a regional classification has been adopted. According to this plan the deposits of each of the larger streams will be described separately, though reference will be made to other areas where similar or related deposits occur and their genesis, so far as known, will be stated.

The Noatak basin formerly contained extensive valley glaciers. The limits reached by the ice have not been determined, for with the waning of glaciation great glaciofluvial outwash deposits mantled most of the lowlands, effectively concealing many of the older deposits and the previous topography. It is believed, however, that the



4. GLACIER AND GLACIAL DEPOSITS, ALATNA RIVER.



5. ICE CLIFFS IN BANKS OF THE NOATAK.



A. MORaine NEAR OUTLET OF LAKE SELBY, KOBUK RIVER.



B. LAKES ON OUTWASH PLAIN, UPPER NOATAK RIVER

glaciers originating in the headwater mountains did not extend as far as the camp of August 11, at the east border of the second highland province, and the glaciers formed in the hills north of the Mission lowland do not appear to have extended to the sea within the explored area. With the more complete disappearance of glaciers, except in the protected mountain recesses, the Noatak began to excavate and reassert the material. Of the older buried deposits little is known except where they are exposed in the natural sections along the streams.

Most of the older outwash deposits seen are composed of fairly well stratified material but contain many irregular boulders, the largest weighing a hundred tons or more. These boulders were seen in various stages of emergence from the gravel deposits in which they occur, and were particularly evident at places where the older deposits had been transected by streams where they formed rapids in the river.

In some of these deposits bones of extinct animals were found. In water-rounded and stratified gravels on the north bank of the river below the camp of August 12 portions of the skull and limbs of a mammoth were found. In the gravels of the first stream below the camp of August 7 and on the stream about 6 miles above the camp of August 12, on the south side of the river, pieces of the tusk of a mammoth, evidently washed out of the higher level deposits, were found in the present creek gravels. The natives report that a good deal of fossil ivory is found in the deposits, and they keep a careful lookout for it when traveling along the river, as it has a cash value of about a dollar a pound. Fragments of various bones from the mammoth, all considerably waterworn, were seen near many of the abandoned native camps.

In the upper part of the outwash deposits at many places are beds of ice, more or less mixed with muck and silt, but in places almost pure. A typical ice bed 20 feet or more thick is shown in Plate XII, *B*, which represents a place between the camps of August 18 and August 19. At this place masses of ice are exposed in the banks of the Noatak up to an elevation of 150 feet above the river. Upon the ice lies a thin cover of silt and forest litter on which spruce trees and other vegetation are growing, as is shown in the view. Where exposed the ice melts rapidly, the water drains away, and the muck and débris collect as a sticky mud. Twigs and branches of willow and spruce are in places interbedded in peaty layers with the ice, indicating alternations of deposition and of land surfaces. No mammalian remains were found associated with the ice beds. Owing to the rapid melting caves and pinnacles are formed and where these occur in the river banks the material is constantly dropping into the stream, the large fragments that break off endangering small boats by the waves they

create. Ice beds of this sort were seen at short intervals all along the Noatak from the camp of August 4 to the mouth, except where the hills are close to the river.

The general aspect of the topography to which these older deposits give rise in the Noatak basin is fairly well shown in Plates IV, V, and VI, but Plate XIII, *B*, taken from the terrace back of the camp of August 1, in the eastern part of the Noatak Valley, shows certain features in somewhat more detail. In this view the Noatak appears at the right with the bare stream-gravel flood plain in process of formation. An earlier flood-plain deposit in which the river is intrenched lies 6 to 10 feet above the level seasonally overflowed by the river and forms the central part of the view. This plain has been cut in an older outwash deposit whose surface rises 100 to 150 feet above the river. The slopes leading to this higher level are as steep as the angle of repose of the material. Lakes of irregular form, which differ greatly in size, lie here and there on the upland. One of these lakes, seen toward the left of the view given in Plate XIII, *B*, stands in a position which indicates that it probably lost some of its former extent by the cutting of the now abandoned flood plain already noted. Above this rather prominent terrace at least four other benches may be seen on the hillsides to the left, the highest being at least 500 feet above the river.

It is evident from this view that various stages of valley filling and reexcavation are recognizable. In this rapid exploratory trip the different levels could not be correlated and the elevation of the highest deposits could be determined only at long intervals and often at unfavorable localities. It has seemed desirable, however, to record certain observations on the upper limit of recognized gravel deposits in the Noatak basin. These observations were made at Twelvemile Creek, at Midas Creek, at the canyon, and on the northwestern slopes of the Igichuk Hills. On the hill southeast of Twelvemile Creek water-rounded boulders of granite, which had evidently been transported far, as none of this rock outcrops in the vicinity, were found in great numbers up to an elevation of 1,200 feet above the river or 3,600 feet above the sea, and for 200 feet higher the slope remained constant, as if the gravels might extend to that height. Northeast of the camp of August 2, near Midas Creek, a low bench 120 feet above the Noatak lies about a mile distant from the river. In the next mile are several higher terraces, irregularly distributed, but having rather flat tops. Each of the benches toward the northeast is slightly higher than the preceding one, but the gravels are not very thick, for a knob of schist with a thin layer of gravels on top is exposed at an elevation of 500 feet above camp. The last definite water-worn gravel recognized was a granite boulder at an elevation of 850 feet above camp or over 3,000 feet above the sea. At the canyon of the Noatak well-worn water-deposited material was recognized up to an elevation of nearly

800 feet above the river or 1,400 feet above the sea. Southwest of the camp of August 23 the drainage of the lower slopes of the Igichuk Hills is discontinuous, the creeks emptying into small lakes that have no surface outlet. The topography is strongly suggestive of the familiar knobs and kettles of a glaciated region, but the presence of limestones in the vicinity makes it possible to explain the feature as due to sink holes of peculiar form. Farther away from the river the gravel terraces and benches become smoother and more regular and extend uninterruptedly to an elevation of 800 feet above the Noatak, or over 1,000 feet above the sea. It is possible that the gravels may even have extended 400 feet higher, for on top of the 1,400-foot knob some fragments of black chert, possibly of foreign origin, were found.

In giving the foregoing elevations it is not intended to suggest that they all fall in one continuous plane, for it is far more probable that minor deformations have occurred or that the high deposits, such as that near Twelvemile Creek, may have been formed near the front of a former glacier and had a very steep slope, whereas much thinner and consequently lower deposits were formed elsewhere at the same time. Some evidence of this fact is afforded by exposures north of the Noatak between the camps of July 28 and August 1. At this place a knob that rises 150 feet above the river and that is composed of silt and gravel shows well-marked bedding, which dips south at an angle of about 65° . The silt, which is mainly on the south side of the hill, is but slightly consolidated, though pieces a foot in diameter can be picked up without breaking, and contains considerable vegetal matter, which is not much carbonized. The gravel, which apparently underlies the silt, is not sufficiently well consolidated to stand but forms a loose rubble. The evidence seems to show that the high dip of the silt is essentially the original depositional slope and marks practically the front of the deposit.

Other evidence for the conclusion that the higher gravels did not mark the same continuous plane may be found in the vicinity of the canyon. The peculiar drainage features and the presence of high-level gravels at this place are believed to be best explained by assuming obstruction of the main valley by a glacier deploying from the Kugururok. According to this explanation, the glacier filled the former Noatak Valley and forced discharge along the southern margin of the ice, the ice remaining in this position long enough for the river to carve the canyon so deep that when the glacier disappeared the stream did not resume its former course, which had been partly silted in and blocked by glacial detritus.

Still other evidence is afforded by the deposits and topography in the Mission lowland and Igichuk Hills. Northwest of the camp of August 23 there is a broadly open gap, not over 500 feet above the sea, which appears to have been the former course of the Noatak to the

No definite proof of the amount of ice in the main Kobuk Valley has been obtained, but the effect of the action of the ice on the drainage indicates a body of considerable extent. No frontal moraines of the main Kobuk glacier have been recognized, though the recessional moraines of the tributary valleys, described above, are sharp and definite. Probably the ice, after flowing down the larger tributary valleys, expanded into lobes on entering the Kobuk lowland. Perhaps several lobes coalesced and formed a continuous glacier that occupied the eastern part of the valley. It seems, however, as if the ice in the Kobuk Valley must have been dominantly a stagnant mass rather than a vigorously eroding agent and that it obstructed drainage instead of eroding the surface.

Evidence of this obstruction is seen in that part of the basin between Ambler River and Reed River. The details of the history of this obstruction have not been worked out, but it appears that at one time the glacier occupying the valley of Lake Selby extended across the Kobuk Valley and abutted on the Lockwood Hills, forming a lake upstream—that is, east of this barrier. As the lake rose its surface at last reached the elevation of the lowest sag across the Lockwood Hills and spilled over. The channel thus formed was eroded rapidly until it became a narrow gorge, cut down to an elevation of about 800 feet above sea level. This now appears as the transverse gap in the hills about 17 miles east of the mouth of Pah River. The narrowness of the gorge and the character and relations of the deposits point to the conclusion that the erosive agency was water rather than ice. The evidence of the high level of the lake is shown by gravel terraces and irregular deposits up to an elevation of 1,000 feet above the Kobuk, or 1,400 feet above the sea.

With the unblocking of westward drainage by the retreat of the Lake Selby glacier it appears that a lower gap was uncovered in the place now marked by Pah River. Farther downstream the large Ambler glacier still obstructed westward drainage, and it is by no means improbable that the Kogoluktuk and Mauneluk glaciers also may have formed barriers to free westward discharge. This stage is marked by large gravel terraces 200 to 300 feet above the Kobuk. With farther retreat of glaciation the Ambler obstruction was removed and free westward drainage was permitted. It is difficult, however, to explain why the transverse southward drainage by way of the Pah was abandoned and the present northward drainage established. The full explanation would undoubtedly involve a number of connected incidents, such as the unblocking of the western discharge, the diminution in the amount of water, the glaciation in the Zane Hills to the south, the reversal of course through capture, and possibly also tilting.

Deposits were formed not only in places where obstructions caused diversion of drainage, but even where a free discharge was permitted,

at localities where glacially eroded materials were deposited beyond the front of the ice. It is impossible to indicate the extent of the modifications of the topography produced by this enormous outwash of material. Without doubt much of the Kobuk lowland and the lowland north of the Cosmos Hills is formed of this group of deposits, though definite criteria are now unrecognizable, as the gravels have been partly transported by running water.

With the disappearance of glaciation the new drainage lines that had become established were continued and the temporary lines, due only to the ice occupation, were abandoned. As a result channels marking short-lived discharges, now unoccupied by streams, are represented by passes, such as that between Wesley and Ruby creeks or the divide at the head of Cosmos Creek. With the development of the new drainage lines the streams in some places were forced to excavate part of the glacial filling of their valleys; in other places glacial erosion had deepened the valleys, so that stream deposition took place; in still other places glacial modification was so slight that the streams flow almost on the preglacial surfaces.

Considerable space has been devoted to describing what is known or surmised about the conditions under which these deposits have been formed, for the questions involved are not only of academic interest but are of practical importance, as a full understanding of the processes and conditions under which these deposits were formed would undoubtedly contribute greatly to the successful search for placers and prevent much useless exploitation.

In the vicinity of Squirrel River and at a few points farther down the Kobuk, as well as near the camp of August 25 on the Noatak, deposits of well-sorted and rounded gravels, composed almost entirely of quartz pebbles, form notable terraces up to elevations of about 400 feet above the sea. These and the other deposits near the mouth of the Kobuk have not been studied closely enough to determine their mode of origin. It is probable that some of them are of marine or fluviomarine origin, the origin suggested for certain of the deposits at the mouth of the Noatak.

Koyukuk basin.—The older gravel deposits of the main Koyukuk Valley have not been examined critically and little is known about them, except that probably in large measure they are formed of the outwash from the various tributary streams during the maximum period of glaciation. So far as known, glacial ice did not reach the valley of the main river, but the evidence as to the foremost stand of the ice is obscured by the later deposits. Although little is known of the deposits in the main stream valley, those in the valleys of Hogatza, Alatna, and John rivers have been seen in some detail and the facts learned about each will be given in the following pages.

The larger part of the Hogatza drainage basin up to an elevation of about 1,000 feet is gravel filled. Only the western and north-western part of this lowland has been examined and its eastern part may possibly connect with the low area that extends westward from the Alatna near Siruk Creek. The Zane Hills, which bound the basin to the west, were the source of small valley glaciers that formed moraines and outwash deposits which constitute the dominant topographic features of this part of the basin. The deposits show a wide range in character of material, but most of them appeared to be waterlaid.

The deposits along the northern margin of this lowland, where the gravels lap up on the south side of the Lockwood Hills, contain many boulders, apparently derived from areas outside the present basin. No deposits formed by glaciers originating in the Lockwood Hills were recognized, and whatever ice existed in these hills was probably so small in amount that it was relatively ineffective as an agent of erosion and transportation. An outline of the conditions under which certain of the deposits in the northern part of the Hogatza basin were formed has already been given in the description of the former spillways of the ice-impounded waters of the Kobuk (p. 96). Here as there many details are still obscure and much investigation will be required to elucidate them satisfactorily.

The Alatna basin has undergone extensive glaciation of a valley type, as is shown by many of its topographic features, such as truncated spurs, oversteepened slopes, and the locally overdeepened valley floor. The whole form of the Alatna Valley shows that it was modeled by a larger and less wieldy agent than running water and then been partly filled in and partly reexcavated, so that the present streams show courses discordant with that of the valley. Only the deposits, however, will be described here, not the erosional forms produced by glaciation. No topographically recognizable moraines were noted in the valley, but resorted deposits, containing large angular boulders, apparently ice transported, were found in many places. About 13 miles south of the junction of Helpmejack Creek and the Alatna there is a deposit of blue clay containing striated pebbles, which was probably formed of glacial rock flour. Ice-transported erratics and outwash deposits have been found up to heights of more than 2,000 feet above the main river. On the hill slopes west of the camp of July 12, below Lake Takahula, well-rounded granite and other far-transported float was found up to an elevation of 1,800 feet above the Alatna, or over 3,000 feet above the sea. On the northern divide of the valley heading in the glaciers west of the camp of July 16 are several foreign erratics. One of these was an angular block of granite, 10 feet in shortest dimension, perched on exposed schist bedrock in such relations that it must have been brought and deposited by a glacier heading in essentially the same region as the

existing glaciers (Pls. VII, *B*, p. 33, and XII, *A*, p. 90), but at least five times as large.

Some ice from drainage basins now separated from the main Alatna River entered the valley during the period of maximum glaciation. As already noted, Mendenhall¹ pointed out that ice from the Kobuk discharged into the Alatna. He states:

Along Helpmejack Creek and the middle Alatna drainage changes have taken place that are best explained by glacial action. The direct topographic continuation of the upper Helpmejack Creek Valley is eastward into the Alatna by the pass which leads to the latter stream in the vicinity of Rapid City, but Helpmejack Creek at present leaves this broad open way, turns to the south at right angles to its logical course, and reaches the Alatna at Beaver City. Such a course was probably originally a spillway for glacial waters and in it Helpmejack Creek became intrenched while the more northerly outlet was still occupied by ice. Upper Helpmejack Creek occupies a filled valley, but not a systematically filled one. The valley is occupied by incompetent meandering streams and numerous small ponds at varying elevations. Its ridges and terraces while of waterworn sands and gravel, so far as examined, are at no constant elevation and bear no obvious relation to each other. In short, the topography and stream alignments are of the confused type which results from ice-work and are in strong contrast to the more regular types which are due to normal stream growth.

Another pass to the east of the main Alatna River, near Lake Takahula, served also as a spillway for both ice and water. This place, which is known by the natives as Akabloouk, meaning "day-light through the hills," is a broadly open saddle at an elevation of about 400 feet above the Alatna. It was formerly occupied by drainage diverted to Malemute River, a tributary of the Alatna, when southward drainage was obstructed by the Helpmejack or Takahula glaciers.

Although the older gravels extend to considerable elevations in the Alatna Valley, those having the strongest topographic expression are from 50 to 200 feet above the river. These gravels are well stratified and water rounded, being similar in general features to those in the Kobuk and Noatak basins. Certain unusual features were noted, however, near the camp of July 8, where the gravels on the southwest side of the river, near the top of the bench 50 to 100 feet above the river, are thoroughly cemented into a conglomerate from 5 to 25 feet thick, which extends for a distance of over a mile. Large blocks of this conglomerate, which have been undermined by the removal of the unconsolidated gravels beneath it, have fallen down and form notable objects along this part of the river. In this same general region brown, heavily iron stained high-level gravels are much more common than elsewhere.

The following description is quoted from Schrader's report² on the Pleistocene deposits of the John River region. The term "till,"

¹ Mendenhall, W. C., *op. cit.*, pp. 46-47.

² Schrader, F. C., A reconnaissance in northern Alaska: Prof. Paper U. S. Geol. Survey No. 20, 1904, pp. 64-66.

used in his description, is probably equivalent to the term "outwash deposit" used in this report, and it is doubtful whether the word "till" can be correctly applied to any of the deposits.

In the lower part of the intramontane section of John River, where the valley occasionally widens, it is sometimes floored by a till sheet from 50 to 100 feet thick, containing ponds and lakelets, some of which seem distinctly to be of glacial origin. Till is prominent also in the mouths of some of the side valleys, as Till Creek valley, which opens into that of John River on the east at about the sixty-eighth parallel. Here good exposures show the deposit to be typical till. It has a thickness of at least 100 feet and forms a broad terrace or sort of small, triangular plateau a mile or more in extent, occupying the mouth of the side valley. It slopes westward to where John River has been crowded to the bluffs on that side of the valley. On the east it overspreads and conceals the lower benching and bedrock topography. Till Creek, a torrential stream, flows in a small canyon whose steep banks are formed of the boulder clay or ground moraine.

In the region of Fork Peak, near the head of John River, at the confluence of several of its tributaries, the valley is wide and open and is floored by a till sheet at least 150 feet in thickness. The surface declines to the southwest, denoting that the deposit has largely come from the northeast, a view which is supported by bedrock strise farther down the valley. The till ascends the northwest slope of Fork Peak to an elevation of 2,500 feet and may continue much higher, but becomes obscured by younger talus and coarse débris of doubtful character, which, however, also exhibits an ill-defined terminal moraine topography. At the elevation of about 3,500 feet is a bench overlain by talus and drift, which, judging from topography, was probably largely deposited by a local hanging glacier.

The John Valley till sheet extends across the divide by way of Anaktuvuk Pass and is continuous with that of the Anaktuvuk Valley and the Arctic slope. At the pass the valley is 3 miles wide and open, and its surface is so flattened with infilled drift that the small streams descending from the mountains in this locality are deflected by the merest obstacle to either side of the divide, flowing sometimes northward by way of the Anaktuvuk to the Arctic and at others southward to John River and the Yukon.

At the pass occur lakelets of glacial origin. One of these, Cache Lake, just northeast of the divide, is 30 feet or more deep. Its surface lies about 100 feet below that of the adjacent ground moraine, giving for the till sheet here a thickness of at least 130 feet. Just south of the pass the till sheet formerly extended entirely across the valley, as is shown by the flat-topped outlying remnants of ground moraine in its middle. These rise to a height of more than 100 feet above the stream and accord in level with the ground-moraine terraces on either side.

On the whole, the till sheet in this northern part of the range seems rarely to extend up the side slopes to more than 500 or 600 feet above the floor of the valley * * *.

Naturally, the side valleys in this region were among the last to become free from glaciers, some of which probably remained long after the disappearance of the ice from the adjacent parts of main valleys. This is shown by the presence of relatively fresh terminal moraines in the side valleys. Four miles northwest of the middle of John River valley the small valley of Contact Creek is crossed by such a moraine. It is typical, being about 60 feet high and one-fourth of a mile in length, measured parallel with the valley. A similar but older feature occurs in John River valley near the middle of the range, about 12 miles in a direct line south of the sixty-eighth parallel. Here the valley flat is crossed by a terminal moraine about 60 feet high. * * * It still forms a continuous ridge or dam across the valley, except where the river has cut a notchlike passage 200 yards wide at the left. At the right the moraine seems to be continuous with the till sheet, which is 10 to 20 feet thick, and

rests on the bedrock benching at a height of about 100 feet above the river. As seen looking parallel with the valley the ridge presents an undulating profile and is sharp crested, owing to its upstream side being cut away by the river. Though it exhibits but little of the typical hummock-and-kettle topography of a terminal moraine, it is composed mainly of typical boulder clay carrying striated pebbles and boulders, some a foot or more in diameter. The materials noted are of the same constitution as those of the river gravels, there being no erratics. The principal surface or front of the moraine, which slopes southward, supports a growth of spruce, some of the trees having a basal thickness of 1½ feet.

A few miles above this moraine occurs the last lingering remnant of the John Valley Glacier. It consists of a lone, roughly circular mass of ice about 300 feet in diameter, rising from the middle of the gravel-covered valley flats to a height of 60 feet. * * * At the top the ice terminates in several distinct knoblike prominences projecting 10 to 20 feet above the main mass. One of these is cylindrical or pipe shaped. The others are crudely pyramidal. The ice is partially capped and flanked by a deposit of genuine till from one to several feet thick, to whose protection it doubtless in large measure owes its preservation. From three sides small streamlets of light-colored muddy water, arising from the melting of the ice and thickened with glacial rock flour from the till, flow down and deposit their load of fine, argillaceous sediment over the flats around the foot of the mass. This glacial mud is of very light color. It is sticky and differs decidedly from the present stream deposits of the valley. This ice mass is undoubtedly a remnant of the John Valley Glacier. Its presence at this late date, after apparently all the other glacial ice has disappeared from the surrounding region, together with the rounded topography of the adjacent mountains, already noted, suggests that this locality is probably near what was the belt of maximum precipitation, and consequently of maximum ice accumulation, that traversed the mountains during glacial time, and is therefore among the last to become free from ice.

Other areas.—The only other known extensive deposits of the older gravels are in Seward Peninsula and in the vicinity of Selawik Lake. The deposits of Seward Peninsula have been adequately described in several Survey reports and require no comment here further than the statement that glacial deposits have not been observed in the portion of the area represented on Plate II. The deposits are of fluviatile, marine, or extraglacial origin, or were formed by combination of processes.

The region in the vicinity of Eschscholtz Bay and Selawik Lake is not well known and the literature concerning it is less available, so it will be described here somewhat fully. The following quotations give the principal results of observations made by Quackenbush¹ on the older deposits. Along Eschscholtz Bay—

high bluffs face the water all around except at the wide Ahweengnuk delta and for a few miles to the westward of the mouth of Buckland River. * * * The bluff does not end, however, at Elephant Point, but bends to the south and continues around the western and part of the southern shores of Goose Bay. * * * At the base of Elephant Point the bluff is 15 feet, rising less than a mile to the west to the altitude of 120 feet and gradually descending to a height of 20 feet at the opposite end * * *. The bluffs on Goose Bay have apparently been entirely neglected by

¹ Quackenbush, L. S., Notes on Alaska Mammoth Expedition of 1907 and 1908: Bull. Am. Mus. Nat. Hist., vol. 26, 1909, pp. 87-130.

writers, although they are continuous with the historic bluff and contain most of the species of fossil mammals found at this latter place. From the base of Elephant Point the bluff rises southward to the maximum height of 75 feet and descending again forms a bank 25 feet high at the first bend of Lost River * * *.

A bluff stretches without a break from Choris Peninsula eastward along the north shore of Eechacholtz Bay and is continued up the Ahweengnuik Valley in the form of a terrace. For a distance of 7 miles the bluff is being cut by waves and its structure beginning at the rocky hill on the base of Choris Peninsula is as follows: First, yellowish, sandy silt without trace of stratification, half a mile long, 50 feet high, tapering down to 18 feet; second, flat terrace, 18 feet high and 1½ miles long, composed of fine dark bluish-gray silt, containing a few small irregular layers of peat; this terrace extends across the base of Choris Peninsula and several miles north along the shore of Kotzebue Sound; third, fine light-colored sand and silt, stratified, three-quarters of a mile long, 35 feet to 70 feet high; fourth, fine grayish silt (like that at Elephant Point) 4 miles long, 30 to 40 feet high; fifth, a section 150 feet long exposing several alternating strata of sand, coarse gravel, sand, and fine gravel, overlain with a thick deposit of fine light-colored silt; the coarse gravel stratum and some of the others are sharply cross bedded. From this point east the beach is broad and high and the bluff is almost entirely overgrown with grasses, moss, and low willow bushes. The few bare slopes near the top and the material brought to the mouths of numerous spermophile burrows indicate that this part of the bluff, averaging about 35 feet high, is formed of a deposit of sand containing many small round pebbles and overlain with from 5 to 11 feet of yellowish silt. No fossils were found east of the cut sections. The terraced section of the bluff near Choris Peninsula is vertical and there is a soft clay flat in front of it. The remainder of the steep-cut portions is bordered by a low sandy beach. Some trifling patches of ice, which had been formed in fissures near the surface, were exposed in the fourth section.

Fossils were collected on the flats and beaches at the bases of all five sections of the cut bluff and two specimens were found on the talus in the third section. A mass of sticks cut by the teeth of beavers was seen embedded near the top of the bluff at the western end of the second section * * *.

High bluffs extend all around the outer curve and along the southern side of Selawik Lake. The bluff is cut in a few places on Selawik Lake for a distance of 15 miles from the outlet, but it appeared to be entirely overgrown with vegetation to the east and was not examined further. The deposit is mostly unstratified sand containing considerable gravel; in some parts silt lies on the top, in others the bluff is composed entirely of silt. A few small fragments of mammoth tusks and caribou bones were found on the gravelly beach, but no fossils were seen on the bluffs.

On the south side of Hotham Inlet there are some cut bluffs 100 feet in height composed of silts, but containing near the top an ill-defined stratum of water-worn gravel and boulders up to 6 feet in diameter, which are embedded in the fine sediment and must have been deposited by floating ice. The gravel consists of quartz, conglomerates, gneissoid rocks, and shows no signs of glaciation; one rounded lump of black bituminous coal was collected in the talus. In the southwestern angle of the inlet a vertical section shows that this portion of the bluff is sharply divided into very thin horizontal strata from top to bottom. A steep continuous bluff of yellowish silt extends along the west side of Hotham Inlet for at least 15 miles to the north; it varies from 50 to 100 feet in height and occasionally shows some signs of stratification. Several pieces of mammoth tusks and some small unrecognizable fragments of bone were found on the gravel beaches or in the water along Hotham Inlet, but only one specimen—the metatarsal of a horse—can be definitely stated to have come from these barren deposits; it was found on the talus on the west side of the inlet about on the latitude of the Arctic Circle.

AGE AND INTERRELATIONS.

The earliest known data on the age of certain of these deposits were furnished by Kotzebue,¹ who found fossils at Elephant Point. These fossils were examined and described by Eschscholtz, who regarded them as Pleistocene. Subsequently this place was visited and described by many others, notably by Beachey in 1826, Dall in 1885, Maddren in 1904, and Quackenbush in 1907. None of these writers appear to question the Pleistocene age of the beds.

Certain clays and ice beds on the Kobuk, reported by Cantwell, were correlated by Dall² with the deposits at Elephant Point and were named by him the Kowak clays and assigned to the Pliocene or Pleistocene(?). Dall states that these deposits do not extend to Noatak River, but the descriptions of that stream given in this report (see pp. 91-92) show that they do.

Gradually, as more of the region was explored and data were accumulated, fossil mammoth and other remains were found at many places. From the foregoing description of the older deposits it is evident that most of them were formed during or after the period of maximum glaciation, but it is not yet possible to determine their age more specifically, for the time relation of maximum glaciation in this part of Alaska to that in the United States is not certain. It is probably true that in a broad way the period of greatest glaciation was synchronous in the two regions, but that it was precisely coincident, even in a geologic sense, is by no means demonstrated. In addition to the deposits formed while the ice was at its greatest extent there are others that were formed subsequently, and certain of these later deposits are so new that they undoubtedly belong to the Recent epoch. The older gravels therefore include deposits ranging in age from Pleistocene to Recent.

It is not unreasonable to suppose that certain earlier beds may subsequently be recognized in the areas now mapped as formed of the unconsolidated deposits. For instance, the coastal plain deposits near Nome, which are in many ways analogous to the high-level gravels skirting Kotzebue Sound, contain fossils which Dall³ has identified as pre-Pleistocene, and it would therefore not be at all surprising if further investigation should disclose late Tertiary sediments in this region. That the extent of such sediments is probably slight, however, seems certain, and the bulk of the deposits here described are believed to be of Pleistocene to Recent age.

¹ Kotzebue, Lieut. Otto von, *Voyage of discovery into the South Sea and Bering Straits*, London, 1821, 3 vols.

² Dall, W. H., and Harris, G. D., *Correlation papers—Neocene*: Bull. U. S. Geol. Survey No. 84, 1892, pp. 265-268.

³ Dall, W. H., *Climatic conditions at Nome, Alaska, during the Pliocene*: Am. Jour. Sci., 4th ser., vol. 23, 1907, pp. 457-458.

RECENT DEPOSITS.

MARINE GRAVELS.

The recent marine gravels occur along the coast and are confined practically to deposits in process of formation. They vary greatly in lithology and physical features from place to place. In deposits near rocky headlands large boulders, formed of the rocks in the neighborhood, predominate. In deposits farther away the material is finer grained; the softer minerals having been removed, the more resistant materials remain. Here and there muds and silts have been deposited and sands and gravels are absent. Some deposits near the mouths of streams consist of mixtures of fluvial and marine sediments. Practically all the recent marine deposits are not permanently frozen. The deposits, so far as known, are not consolidated but consist of uncemented silt, sand, gravel, or boulders.

No sections of typical marine gravels along this part of the Arctic coast have been examined, so that little is known of their features other than those seen on the surface. Furthermore, as has been already pointed out, only the recent marine gravels are included in the section, the deep marine deposits or those occurring at a considerable elevation above sea level having been omitted. Consequently the recent marine gravels may be considered as forming a narrow fringe along the coast and having rather slight thickness.

STREAM DEPOSITS.

The stream deposits are of greatly diverse types, their character depending on the history and relations of the streams by which they were formed. Some of the smaller streams have eroded their valleys and laid down deposits under the same local conditions that now prevail in their drainage basins. The deposits in such a valley are formed of the rocks outcropping in the basin, and their features are characteristic of deposits formed by ordinary single-cycle streams. A stream of this type, however, is rather the exception than the rule, for most of the streams have had a more complex history. The valleys of some of these streams of more complex history show an interruption in the orderly succession of events, whereby decrease in gradient has caused the building up of the valley floor. In other places increased slope has renewed degradation. In still other places several activities have combined, and the present stream is eroding former stream-deposited gravels. In such places the gravels, instead of being formed of rocks of local origin, may have come from outside the present drainage basin of the stream, and instead of having the features of ordinary river gravels may, through this double concentration, have become more rounded and better sorted.

Not only may the present streams be rehandling former stream gravels, but they may also be traversing unconsolidated deposits formed by other agencies. For instance, the greater part of the floor of the present Kobuk and Noatak rivers is carved in deposits of glacial and glaciofluvial origin, already described (see pp. 90-97), and as a consequence the present stream deposits resemble in large part the older deposits. This is particularly notable on the Noatak, where large boulders washed out of the earlier deposits form numerous rapids in the stream, line the banks at low water, and are being built into deposits that are distinctly abnormal for a single-cycle stream.

At several places mountain glaciers give rise to streams that are forming deposits characterized by features due to their double mode of origin, consisting of normal stream deposits mixed here and there with large, irregular ice-transported blocks. The fine material in such deposits also differs from that of the usual stream deposits in that it is mainly a product of glacial erosion rather than of normal weathering.

In many places the stream gravels so merge with the deposits of marine origin that it is impossible to separate the two. This is especially true in the delta of the Kobuk and at the mouths of other streams. This interrelation is further complicated by the fact that at several places ancient bench deposits, such as occur near the mouth of the Noatak, are being subjected to the action of marine and fluvial agencies, so that the resulting deposits show the results of three processes.

Examples to show the great diversity of the stream gravels in the region might be multiplied, but the foregoing indicate some of the more common types. All these deposits show certain more or less universal features. All the material is unconsolidated and has been subjected to more or less sorting prior to deposition. Practically all the shallow recent stream gravels are not permanently frozen, a fact that is of considerable economic importance, for the physical condition of the gravels with respect to cementation by permanent frost exercises a considerable control on the development of mining. The data concerning the presence or absence of permanent frost are not sufficiently complete to permit a final statement as to the distribution of frozen and unfrozen deposits, for artificial sections are almost entirely absent and in natural sections the surface exposed to the heat and air is thawed, even in deposits that are permanently frozen.

GLACIAL DEPOSITS.

Recent glacial deposits occur only in the vicinity of the existing glaciers and are therefore limited to the mountain regions. They have been seen only at the headwaters of Alatna and Noatak rivers,

though, as has already been pointed out, small glaciers probably occur at the headwaters of some of the tributaries of the Kobuk and of the branches of the Noatak west of the headwater mountains.

All of the recent glacial deposits are relatively small in extent and in volume, so that they have not been distinguished on the geologic map (Pl. II). Those that occupy areas sufficiently great have been included with the other recent deposits, but most of them are too small to be shown on the map or to be differentiated from the more ancient glacial and glaciofluvial deposits.

Plate VII, *B* (p. 33), already described, is a view of one of the glaciers in the Alatna River basin and illustrates certain of the glacial deposits. The form of these deposits may be best seen at the margin of the lobe to the left, but the character of the material is most evident in the lower right foreground. A picture that shows better the character of the material being deposited by this glacier is afforded by Plate XII, *A*, which is a view taken from below the end of the glacier. In this view the steep talus-covered slope in the center is the front of a glacier bearing on its surface unsorted blocks of various shapes and sizes. The rather abrupt change in slope of the surface of the glacier occurs at an elevation of fully 800 feet above the observer, and the large block of granite a third of the distance down from this point to the end of the glacier is at least 50 feet in diameter.

Beyond the front of a glacier there is, as has already been noted, a combination of glacial and fluvial action, which so mingles two types of deposit that no sharp line of separation can be drawn between them, producing a condition that is well illustrated by the foreground in Plate XII, *A*. This part of the view shows large, irregular blocks which were originally deposited mainly by ice, but which have been subjected to stream erosion and transportation and have lost part of their glacial aspect, yet have not completely gained stream-deposited features.

IGNEOUS ROCKS.

The igneous rocks of the Noatak-Kobuk region may be divided into many different groups, the lines of division depending upon the particular features on which emphasis is placed. The most important criterion here used in their classification is their age, which is also expressed by their lithology, for in this region the rocks belonging to a single period of igneous activity are of fairly uniform character. The various rocks, therefore, although in part given lithologic names, have been grouped according to their age into four main divisions—the greenstones, the early basic intrusives and effusives, the granitic rocks, and the late lavas or basaltic effusives. They are here named in the order of their age, beginning with the oldest, and will be described in that order.

GREENSTONES.

DISTRIBUTION AND GENERAL CHARACTERISTICS.

Greenstones have been observed wherever the old undifferentiated schists form the main country rock. Thus they have been reported in the Totson group on John River, in the central part of Alatna River, in the Kobuk basin, and at several places in Seward Peninsula. In none of these localities, however, do these rocks present extensive exposures; they occur rather as narrow dikes and sills, generally parallel with the cleavage of the other rocks. Usually they are much sheared and their original structures and even their original mineral composition are changed.

Schrader¹ includes the greenstones of the John River basin with the Totson group but states:

The series is believed to be essentially of sedimentary origin, but the sedimentation seems to have been accompanied by basaltic flows, which were later sheared with the sedimentary beds, giving rise to amphibolite schist, of which the most prominent strip, having an apparent width of several miles, occurs near the southern part of the belt occupied by the series. Here the rock, judging from the bent and crushed remnants of feldspar and augite shown under the microscope, is plainly of igneous origin.

In the Alatna River basin greenstones were seen both by the expedition of 1911, and by Mendenhall in the vicinity of the Helpmejack Creek. Mendenhall² states that the country rock in this vicinity is "cut by intrusive greenstone masses, which are themselves much altered and have been rendered schistose. Sufficient of their original structure, however, remains to determine them as diabases."

Further information obtained by the expedition of 1911 shows that similar rocks cut the limestones near Cache Creek between the camps of July 11 and 12. The contact between the two rocks was not actually seen, but inclusions of limestone in the greenstone and the presence in the limestone of contact-metamorphic minerals, such as tremolite, clearly confirm the conclusion reached by Mendenhall. Under the microscope the rock appears almost entirely recrystallized. Albite is the most abundant mineral. It occurs as secondary crystals with inclusions of magnetite, epidote, and chlorite. Chlorite derived from the metamorphism of earlier iron-rich minerals, such as biotite or amphibole, is also abundant and is chiefly the mineral that gives the rock its greenish color. Magnetite in well-formed octahedra is recognizable, even in the hand specimen. Quartz, calcite, pyrite largely altered to limonite, epidote, and apatite form a smaller part of the rock. The rock shows a marked schistose structure and there is no question but that it is a metamorphosed igneous rock.

¹Schrader, F. C., A reconnaissance in northern Alaska: Prof. Paper U. S. Geol. Survey No. 20, 1904, p. 59.

²Mendenhall, W. C., Reconnaissance from Fort Hamlin to Kotzebue Sound, Alaska: Prof. Paper U. S. Geol. Survey No. 10, 1902, p. 34.

Farther up Alatna River, west of the camp of July 12, in the limestone near the top of the 3,200-foot hill, are sheared sills or dikes of greenstone schist having many of the features noted in the preceding locality. Specimens from this place, however, show in addition to the recrystallized albite a considerable amount of hornblende, which was not recognized in the other rock, though originally it may have been present and have been subsequently altered to chlorite. Small amounts of magnetite also occur in the rock, but other minerals are practically absent.

Igneous rocks that have been subjected to pronounced deformation and attendant metamorphism have been recognized in the Kobuk region in the vicinity of Shungnak and at Squirrel River. In the Shungnak region greenish igneous schists were recognized in the hill east of the Kogoluktuk and at several places in the ridge between Wesley and Cosmos creeks a mile or so south of Iron Mountain. At the latter place the igneous schist appears to cut the underlying slates and forms a sill between that rock and the overlying limestone. So far as observed it does not cut the limestone nor does that rock show any contact effects. Metamorphism of the rocks as a whole, however, has proceeded to such lengths that the absence of contact metamorphism is not conclusive. These older igneous rocks have schistose structure, are greenish in color, and consist mainly of greenish chlorite and plagioclase feldspar, the latter as a rule completely recrystallized.

In the same general region are serpentine rocks, often mistaken for jade, that appear to be analogous to the greenstones. One exposure of these rocks in place was examined at the head of Dahl Creek. Specimens of this greenish compact fine-grained dike rock were found to consist of magnetite and pyrite inclusions in a microcrystalline groundmass of serpentine. The rock is but little sheared, and for this reason considerable doubt is felt in assigning it to the greenstone group. From reports of prospectors and others this type is presumably much more extensive in the Jade Hills, west of Ambler River, than it is in the vicinity of Shungnak, but that locality has not been critically examined and little is known of the distribution and extent of this type at that place. The greenstones in the Squirrel River region are essentially similar to the more common type previously described. All of them are considerably sheared and have a distinctly schistose structure. Albite and chlorite are the most abundant mineral constituents and both are later than the original minerals of the rock.

The greenstones of northeastern Seward Peninsula have not been studied in detail. Moffit states that—

dikes and sills of greenstone, such as are seen in the western part of the peninsula northwest of Nome, were not observed in the region. If such are present in the area

immediately south of Kotzebue Sound they are probably so greatly altered that many of their original peculiarities have been lost and they are not now readily distinguishable from the including schistose sedimentary rocks. Altered greenstones are present, but so far as observed by the writer they do not have the form of sills or dikes and appear rather as great irregular masses or stocks.¹

AGE.

The criteria for the determination of the age of the greenstones as a whole are not such as to permit a precise and definite assignment. It has been proved that these rocks cut the undifferentiated metamorphic schists and certain of the undifferentiated Paleozoic limestones and have been subjected to strong dynamic metamorphism. None of these events, however, can be assigned a definite age. The undifferentiated schists (see pp. 60-61) were probably early Paleozoic or possibly pre-Paleozoic. The limestones that are intruded are apparently the same as those on John River, which, as stated on page 65, are probably not older than Silurian nor younger than lower Carboniferous; near Shungnak, however, the greenstones apparently do not cut the undifferentiated Paleozoic limestones. The major period of metamorphism does not seem to have affected the known Carboniferous rocks and in Seward Peninsula appears to have been earlier than the Ordovician.

There are many conflicting lines of evidence, therefore, which lead to diverse conclusions. From general considerations and from analogy with near-by better known areas it seems probable that the greenstones and associated rocks are of Paleozoic age and are probably older than the Carboniferous. How much older is not known and can not even be postulated until further detailed work is done and more of the unknown area is explored.

EARLY EFFUSIVES AND INTRUSIVES.

DISTRIBUTION AND GENERAL CHARACTERISTICS.

There are three principal areas of the rocks here called the early effusives and intrusives—the extreme eastern part of Seward Peninsula, the vicinity of the canyon of the Noatak, and the Zane Hills in the Koyukuk basin. The first two areas, so far as known, have been indicated on the map, but the basic rocks of the Zane Hills have not been distinguished on the map from the sedimentary rocks of supposed Lower Cretaceous age called the Koyukuk group.

The group of rocks in Seward Peninsula has been described by Moffit² as follows:

Andesites are abundant in the Kiwalik-Buckland divide and are probably the surface representatives of an igneous magma corresponding in composition to the deep-seated diorites and monzonites. As already stated, they occupy, where observed by

¹ Moffit, F. H., *The Fairhaven gold placers*: Bull. U. S. Geol. Survey No. 247, 1905, p. 27.

² *Idem*, pp. 30-31.

the writer, a position intermediate between the basic rocks of the western side of the ridge and the central acid ones and form a large part of the watershed. They are of a dark-gray or greenish color and on an exposed surface have a spotted appearance due to the alteration of the feldspar phenocrysts. Both hornblende and pyroxene varieties were seen, the latter containing considerable olivine in addition to pyroxene and showing the secondary mineral iddingsite. Alteration of pyroxene to hornblende was also observed. The feldspar is a basic variety, labradorite or sometimes anorthite, giving as alteration products chlorite and epidote.

Andesite breccias were found at various localities.

In the vicinity of the Noatak Canyon rocks in a measure similar to the andesitic rocks of Seward Peninsula were examined. In general, however, the rocks at the canyon differ from the andesites in that they are mainly of intrusive character, effusive phases being practically absent. Topographically these igneous rocks near the canyon form numerous sharp pinnacles of irregular distribution. In the main they are stocklike masses with dikes and sills here and there radiating out from the periphery. Some amygdaloidal phases were seen and though not parts of surface flows these were in the upper part of dikes near the surface. The filling of the amygdaloids was mainly calcite.

The rocks are medium fine grained and weather to a rusty brown color on exposed surfaces. In hand specimens the only minerals easily recognized are feldspar and pyroxene. Under the microscope the feldspar is seen to be mainly labradorite of an acidic phase. The dark minerals are mainly augite with subordinate amounts of biotite, commonly altered to chlorite, and some magnetite. Sulphides are also sparingly present. The structure is hypidiomorphic granular. From the above characters it follows that the rock is a fine-grained gabbro.

A view of a faulted dike in the Noatak Canyon is shown in Plate XI, *B*. The gabbro forms the right-hand portion of this view and the dark band with the light-colored contact phase in the middle portion. The rocks cut are sandstones, quartzites, and thin limestones belonging to the Noatak sandstone. A few miles west of this place the same rocks exhibit structures characteristic of ellipsoidal basalts in the round boulder-like appearance of the exposed surfaces. Metamorphism is invariably rather strongly marked near the gabbro-sandstone contact for a distance of several feet. This effect is shown by the bleaching of the otherwise dark-colored sedimentary rocks and the greater induration.

The gabbro shows a pronounced jointing and in places a slickensiding produced by faulting, but nowhere was the rock at all schistose.

The eastern locality of early effusives and intrusives has already been described under the Koyukuk group (p. 81). It is unnecessary to repeat the details further than to point out again that amygd-

daloids, tuffs, and volcanic agglomerates occur in the Zane Hills so intricately associated with the arkosic sandstones and conglomerates and other sedimentary rocks that they can only be differentiated after much more detailed study than has at present been attempted. All these rocks are of an andesitic or dioritic composition and texture.

AGE.

The most definite evidence as to the upper age limit of the early effusives and intrusives is afforded in the eastern part of Seward Peninsula south of the area covered in this report and shown on the map (Pl. II). Here similar rocks form boulders in the conglomerate at the base of the Upper Cretaceous section of that region. This definitely places the upper age limit of the igneous rocks as earlier than that period of sedimentation. In the same region granites which are known to cut the andesites and associated rocks intrude fossiliferous Devonian and Carboniferous limestones. Although it has not been proved beyond question that the andesites also cut the Carboniferous rocks, such an interpretation seems warranted by the general relations and structures of the two groups.

In the Noatak region sedimentary rocks younger than the Carboniferous do not occur near the gabbro intrusives, so that the upper age limit of the latter is not directly determinable. The Carboniferous quartzites, sandstones, and shales are intruded and therefore the igneous rocks are later.

In the Koyukuk region the basic igneous rocks of the Zane Hills form pebbles in the Upper Cretaceous conglomerate and sandstones. It has been pointed out (p. 82) that the Lower Cretaceous or Upper Jurassic age of the Koyukuk group as mapped rests on fossils found in certain limestones associated with igneous tuffs and other rocks. If this correlation is correct and the igneous rocks are actually interbedded with the Lower Cretaceous or Upper Jurassic sediments the age of the igneous rocks is definitely settled. However, as the age determination does not rest on incontrovertible facts, there is reason to doubt the validity of the conclusion.

As is noted later (p. 114), the granites, which are probably referable to this same major period of intrusion, cut the early effusives and intrusives. It is therefore open to question whether the supposed Lower Cretaceous sediments associated with the igneous rocks have been correctly correlated or whether they may not in reality belong somewhat lower in the time scale. Whatever may be the correct answer to this query, it seems evident from the facts at hand that the early effusives and intrusives are of Mesozoic age, were probably formed in the middle rather than in the early part of that era, and are certainly older than the Upper Cretaceous.

GRANITIC ROCKS.

DISTRIBUTION AND LITHOLOGIC CHARACTERS.

The rocks here grouped together as granitic rocks occupy in the main three areas—Seward Peninsula, the Zane Hills, and the highlands between the Noatak and Kobuk. In all these regions this group is composed of acidic intrusive rocks of medium fine grain and rather uniform composition. The rocks occur mainly as batholithic masses from which there are numerous small apophyses which intrude the country rock.

In Seward Peninsula there are many places where the granitic rocks are exposed within the mapped area, namely, in the hills forming the Buckland and Kiwalik divide, southwest of Candle; in the central part of the Kugruk basin; and in the divide between the Inmachuk and Cottonwood Creek. All of these localities have been described by Moffit, and the following extracts taken from his report¹ serve to give only one or two typical examples. Near Kugruk River—

the rock is of a light-gray color and has an even grain of medium coarseness. While not differing greatly in appearance from the true granites, it has a somewhat unlike mineral composition, resulting from the presence of a considerable amount of plagioclase feldspar in addition to the orthoclase, the two being present in about equal quantities or with the plagioclase slightly predominating. In thin section the microscope shows plagioclase, orthoclase, hornblende, quartz, and biotite; titanite, apatite, and magnetite are always present. On the basis of the amounts of plagioclase and orthoclase this rock is classed with the monzonites.

The microscopic study of the siliceous schistose rocks of Kiwalik Mountain and the neighboring hills, also of Potato Creek, has led to the conclusion that they also are highly altered granites. The hand specimens show a light-colored, saccharoidal, schistose rock, often slightly stained with iron oxide. In the outer portion of the area the disturbing forces appear to have had greater effect than near the central part, although the entire mass is highly altered. Under the microscope the rock is seen to contain more quartz than feldspar, with minor quantities of muscovite, biotite, apatite, and zircon in grains or rarely in crystals; secondary calcite is rather frequent.

In the Buckland-Kiwalik divide the granitic rocks include—

a number of different varieties—granites, monzonites, and quartz diorites. Hornblende is the prevailing dark mineral of the granites, but at times biotite takes its place. By a decrease in the amount of quartz the granites approach syenites in composition, such phases being characterized by the abundance and large size of orthoclase crystals, which usually show Carlsbad twinning and have roughly parallel arrangement, with the small intervening spaces filled with hornblende, biotite, and a small amount of quartz. Titanite is abundant.

In the Zane Hills the granitic rocks are similar to those examined in Seward Peninsula. They are formed mainly of quartz, orthoclase, and biotite. Microcline, microperthite, and undetermined plagioclase feldspars occur in varying amounts. Hornblende is also a usual constituent. Magnetite and apatite form only a small bulk of the

¹ Moffit, F. H., *op. cit.*, pp. 27-29.

rock, but are nearly everywhere present. Aplitic phases in the small dikes from the larger granite masses were noted at a number of places. None of the granites appeared to have been sheared since consolidation, though some indications of movement during the crystallization of the magma were seen.

In the divide between the Noatak and Kobuk granites undoubtedly occur in large masses. This is inferred from the granite pebbles and boulders in the unconsolidated deposits that have been derived from this region. The rocks in place have been seen only in the mapped area west of the camp of July 16 on the Alatna. The general appearance of the granite and its topographic expression are shown in Plate VII, B. Unfortunately the specimens from this place were lost in transit, so they could not be examined microscopically. Granite from the same general region, however, was found as float on the hillside of the Alatna Valley, high above Lake Takahula, and on the hill east of Twelvemile Creek in the Noatak basin. The specimens from both these places show considerable quartz, with some orthoclase and microcline feldspar and smaller amounts of oligoclase or oligoclase-albite, some mica, mainly muscovite but with a little biotite, usually more or less chloritized, and varying but very small quantities of epidote and garnet.

It is uncertain whether granitic rocks occur north of the Noatak in the hills north of the camp of August 7. The float in this part of the basin is so much mixed that it was impossible to distinguish the source of particular pieces. In this part of the basin float of a coarsely crystalline hypidiomorphic granular rock that is not known to occur in any part of the explored region was found. It consisted entirely of bytownite feldspar and augite, with small amounts of olivine. From this composition it may most appropriately be called an olivine gabbro. The absence of quartz makes doubtful the assignment of the rock to the granitic group previously described, and further explorations will be necessary to prove whether the olivine gabbro should belong to the granitic group or to the early basic effusives and intrusives.

Another rock of unknown distribution and relations which may belong to the group of granitic rocks was found as float in some of the streams in the vicinity of Shungnak. This rock was coarsely crystalline, basic, granular, and made up largely of chromite, with smaller amounts of iron silicates and feldspar. Boulders up to a foot or more in diameter were fairly numerous in Dahl Creek. If this float really belongs to the group of granitic rocks, it will be necessary eventually to split up the group into an acidic phase, characterized by the normal granites, and a basic phase, to which these basic and ultrabasic rocks now known only as float belong.

AGE AND INTERRELATIONS.

The determination of the age of the granitic rocks has already been partly treated in discussing the age of the early basic effusives and intrusives. In that section it was stated that the granitic rocks cut the other igneous rocks in the Kiwalik-Buckland divide and in the Zane Hills and formed pebbles in the conglomerate at the base of the known Upper Cretaceous section. The latter condition is also found to be true of the conglomerate at the base of the same group on the Alatna. It seems fairly certain that the upper age limit that can be assigned to the granitic rocks as a whole is pre-Upper Cretaceous. The lower age limit may be determined on the basis of the assumed age of the early basic rocks. This, however, has been shown to be open to question. There is no doubt, however, that granites in all essential respects similar to those under consideration have been found in the Darby Range of Seward Peninsula, cutting fossiliferous Devonian or Carboniferous limestones.¹ It follows, therefore, that the granitic rocks were formed probably in the Mesozoic and certainly between the known Devonian or Carboniferous and the known Upper Cretaceous sediments.

As already suggested in a previous paragraph, the most widespread period of volcanism in Alaska appears to have been in the Jurassic, and it seems more than likely that these granites were intruded during that general period.

It should be pointed out, however, that a comparatively long period must have elapsed between the early effusives and the granitic intrusives, for the two are formed under such different conditions that there must have been thorough consolidation and considerable burial of the lavas before the granites were injected. It is therefore necessary to take into consideration this interval in assigning a definite age to the igneous activities by which these two groups were produced.

LATE LAVAS OR BASALTIC EFFUSIVES.

DISTRIBUTION.

Late lavas occur chiefly in two areas in the Noatak-Kobuk region, namely, in Seward Peninsula and in the Koyukuk basin.

In Seward Peninsula the most extensive areas are in the extreme southwestern part of the mapped area along the valleys of Inmachuk, Kugruk, and Kiwalik rivers; at several places along the coast, notably west of Cape Deceit; and in the lower country flanking the Kiwalik-Buckland divide. The recent basalts in the latter locality have not been mapped, as their differentiation from the early basic effusives and intrusives has not been effected. It is known that the group is also represented in the Buckland basin, but the region has

¹ Smith, P. S., and Eakin, H. M., A geologic reconnaissance in southeastern Seward Peninsula and the Norton Bay-Nulato region, Alaska: Bull. U. S. Geol. Survey No. 440, 1911, pp. 64-70.

not been critically examined and little is known of the occurrence except that the rocks form rapids 30 miles above the mouth of the stream and prospectors report float basalt in other parts of the basin.

In the Koyukuk basin recent basalts have been seen at three places, but probably further exploration would result in the discovery of other areas occupied by these rocks. The three areas are on Kanuti River, about 30 to 40 miles in an air line east of the mouth of that stream; along the flanks of the Zane Hills, west of the mouth of the Hogatza; and on the northern flanks of the Zane Hills in the pass from the Pah to the Selawik, between these hills and the Lockwood Range to the north.

LITHOLOGIC CHARACTER.

The recent basalts in northeastern Seward Peninsula have been best described by Moffit and the following abstracts¹ have been taken from his published report:

In color the lavas are dark gray, green, or nearly black; they are usually very cellular or even spongy in appearance but at times compact and without the amygdaloidal cavities. Outcrops of the older lavas in place are not plentiful, and the edges of the sheets, where cut through by the streams, are marked by tumbled heaps of blocks resulting from the jointed columnar structure of the lava. In a few places they form flat-topped hills or mesas from 20 to 50 feet high, very conspicuous when viewed from a distance and evidently the remains of a partly eroded sheet. Agglomerates and breccias were observed at several points. A study of the numerous specimens collected shows them to be made up of diabases and basalts, both rich in olivine. In the basalts especially olivine phenocrysts are abundant and very noticeable, even in the hand specimen. Iddingsite is not infrequent as an alteration product of the olivines. * * *

In this region the outpouring of liquid rock took place in not very distant time, for theropy surface and irregular margin are still preserved, just as at the time when the molten stream ceased to flow. Caverns or tunnels, produced by the cooling of the surface and subsequent outflow of the still liquid rock beneath, are numerous. They show a height of 20 to 25 feet and a width in some instances as great as 200 or 300 feet, but rarely have the roofs preserved to the present time, since the weight was too great for an arch of such width. Flattened lenticular steam cavities, 2 to 3 feet in greatest diameter, are sometimes exposed, and the upper surface of the sheet is marked here and there by smooth, irregular elevations produced by the escape of steam and the welling of the lava from below.

Important modifications of the drainage were brought about by the extrusion of the lava, which occupied the depressions and flowed down the valleys in broad rivers of molten rock. At times the cooling of the advancing front wall dammed back the flow and forced it over the low, rounded divides between the watercourses into the next valley beyond, or formed a lake which finally overflowed the obstruction and resumed its original course, only to repeat the process a little farther on.

In this way islands of bare ground were left between the great finger-like protrusions along the edge of the sheet. At the same time a shifting of the watercourses was brought about, for when not of sufficient volume to fill it the lava occupied the lowest part of the valley and the waters sought a new channel parallel to the old one, along the edge of the hardened flow. A number of lakes and ponds also owe their existence to the damming of streams by lava.

¹ Moffit, F. H., *op. cit.*, pp. 31-32.

Mendenhall¹ describes the Kanuti River locality, in the Koyukuk basin, as follows:

Along the middle Kanuti River * * * horizontally bedded vesicular olivine basalts form bluffs 50 to 75 feet high on the north bank of the river, and similar bluffs south of the valley are probably due to the same formation.

On the southeastern flank of the Zane Hills occur numerous exposures of dark amygdaloidal basalt, which form a low ridge north of the Koyukuk. Under the microscope the rock is seen to consist of small phenocrysts of augite and plagioclase feldspar in a fine-grained groundmass of the same material. Magnetite occurs as an accessory and chlorite as a secondary mineral, resulting from the alteration of the augite. The rock as a rule has a much less glassy appearance than the basalts of Seward Peninsula. On exposed surface it weathers to a rusty brown color, but few exposures were seen in which this oxidized layer was as much as one-sixteenth of an inch thick.

In the vicinity of the pass between Pah and Selawik rivers, a reddish-brown lava forms low level-topped mesas of considerable extent. The flows were rather thin, for down some of the small ravines a vertical distance of 100 feet or so were found outcrops of the underlying Cretaceous sandstones and conglomerates. So far as observed the lava was entirely undisturbed. Under the microscope a specimen from this place showed phenocrysts of orthoclase one-eighth of an inch in length in a groundmass of orthoclase, albite, and biotite with accessory magnetite and secondary iron oxides. The red color of the rock is due to the finely divided and widely disseminated iron oxides. This rock has all the features of certain of the lavas from the lower part of the Koyuk basin reported by Smith and Eakin² in 1909. The extent of the lava flow at this locality was not determined, but it undoubtedly occupies a much greater area than that shown on the geologic map (Pl. II). Probably some of the topographic features of the Pah-Hogatza basin will subsequently be shown to have been produced by the barrier formed by the outpouring of this lava, and certain of the high-level gravels may have been formed as a result of drainage modifications it undoubtedly induced.

AGE.

The effusions of recent basalt took place probably in the later stages of the Tertiary and extended down almost to the present time. In the Noatak-Kobuk region the only direct evidence as to the earliest date to be assigned to these lavas is the fact that they overlie Upper

¹ Mendenhall, W. C., Reconnaissance from Fort Hamlin to Kotzebue Sound, Alaska: Prof. Paper U. S. Geol. Survey No. 10, 1902, p. 42.

² Smith, P. S., and Eakin, H. M., op. cit., p. 73.

Cretaceous rocks unconformably. However, as there was a pronounced period of diastrophism that occurred later than the Eocene and as the lavas were not affected by it, it is evident that they were formed subsequent to that event.

The extrusion of lava continued down to a very recent time, as is shown by the freshness of the rocks and the unmodified character of the topography to which they give rise. As already noted, the ropy surface, unfilled gas cavities, and lava-dammed lakes indicate that certain of the flows are very recent. Furthermore, it has been shown by Collier¹ that in near-by portions of Seward Peninsula the recent basalts overlies gravels which are cemented by indurated clays. Mendenhall² found similar conditions in the Koyuk basin, where horizontal recent basalts lie on 5 feet of gravel, which in turn rests unconformably on schists.

All these flows are not portions of a once continuous sheet or of a single extrusion. This is proved not only by the different character of the rocks and the different amount of weathering they have undergone, but also by the fact that at the locality noted in the preceding paragraph Collier found pebbles of an earlier lava in the gravels overlain by the recent basalts. The latter fact shows that there had been an early lava flow, succeeded by a period of erosion in which the gravels were formed prior to the eruption of the covering lavas.

From the foregoing statements it may be inferred that all of the recent basalts were not contemporaneous. Although they probably range in age from late Tertiary to Recent, when considered in a broad way it is believed that they all mark essentially one period of volcanism. Therefore, although many years undoubtedly elapsed between different flows, even in the same district, there are sufficient reasons for assembling the lavas together and regarding them all in a stratigraphic sense as practically a unit.

VEINS.

Although the occurrence of veins is of much importance in the search for valuable mineral deposits, it has not been possible to indicate their distribution on the geologic map (Pl. II) on account of the limitations of the scale. Consequently in the following pages a description is given of the general types of veins recognized and the kinds of rocks in which they occur, and the account of the places where veins carrying ore minerals have been exploited is left to the last section of this report, which treats of the economic geology (pp. 125-157).

¹ Collier, A. J., A reconnaissance of the northwestern portion of Seward Peninsula, Alaska: Prof. Paper U. S. Geol. Survey No. 2, 1902, p. 31.

² Mendenhall, W. C., A reconnaissance in the Norton Bay region, Alaska, in 1900: Special Publication U. S. Geol. Survey, 1903, p. 206.

OLDER QUARTZ VEINS.

The veins of the region may be divided roughly on the basis of their most abundant constituents into two main types, namely, quartz and calcite veins. The former are the most abundant and are economically the most important. The quartz veins are further divisible into many smaller groups on the basis of age or mineral composition. It is not known how many periods of quartz vein formation there were, but at least two appear to be fairly distinct and identifiable—one prior to the profound pre-Mississippian deformation and the other after that period of diastrophism. In the present report the veins formed during the first period are called the older quartz veins, whereas the others are called the younger quartz veins.

From the above definition of the two groups it is evident that the older quartz veins are found only in the undifferentiated Paleozoic metamorphic schists and the undifferentiated Paleozoic limestones. As already pointed out, most of these limestones are believed to be later than the schists, and in the field it is found that the older quartz veins are almost if not entirely confined to the schists. This fact is significant as indicating the general distribution of these veins, for the areas of schist are shown on the geologic map (Pl. II). In all the areas mapped as undifferentiated metamorphic schists, from John River to Seward Peninsula inclusive, representatives of this group of veins were recognized.

As the older quartz veins have gone through the same deformational processes to which the older rocks have been subjected, their field appearance shows evidence of this history. They usually occur as stringers, lenses, and irregular masses of quartz of slight horizontal or longitudinal extent. Plate VIII, A (p. 56), previously described, shows some of these veins in the schists on Alatna River. Unfortunately they are not very distinct in the illustration, but they can be recognized as the light-colored, hard bunches around which the cleavage wraps, a little to the right of the hammer. The veins are discontinuous and, although in places zones or areas having numerous veins are seen, the individual members can not be traced for any distance. This feature is important in determining whether the veins can be successfully exploited as lodes.

The filling of the older veins is almost entirely quartz. Some sulphides or their oxidation products are seen in a few of the veins, but they form an insignificant amount of rock. It is probable, judging from assays made of similar veins in Seward Peninsula, that native gold is also found in the older quartz veins. This fact has not been demonstrated in the Noatak-Kobuk region, but it is believed that this group of veins is the source from which a large amount of the placer gold has been derived.

YOUNGER QUARTZ VEINS.

The younger quartz veins occur widely throughout the Noatak-Kobuk region. Although this group includes all the veins later than the major period of metamorphism, and so may occur in any of the rocks in the region, they, like the older quartz veins, are largely confined to the undifferentiated Paleozoic schists and limestones. Unlike the former group, however, they have been found in the Noatak sandstone and Lisburne limestone. Few if any veins occur in rocks younger than the Paleozoic, so that the distribution is confined to the areas occupied by rocks older than the Mesozoic.

Like the preceding group, there are strong reasons for believing that all the younger quartz veins are not of the same age. Data to permit the separation of the different members of this group, however, are not yet at hand. Many of the younger quartz veins appear as fillings of crevices or gashes in the highly deformed sandstones along the Noatak. A particularly clear illustration of the appearance of these veins is shown in Plate X, A (p. 63), which shows a sandstone outcrop a short distance above the camp of August 13. At this place quartz veins have been formed in the axis of a closely appressed and ruptured fold, transverse to the bedding. The veins are all of slight extent and the filling has the appearance of being derived by infiltration from the adjacent rock. The veins contain practically no mineral other than quartz, and it is believed that gold and other economically valuable minerals are not to be sought in this type of vein.

There are, however, certain of the younger quartz veins, apparently from a deep-seated source, that may contain valuable minerals. Such veins appear to be most common in the black slates and quartzites of the undifferentiated metamorphic schists. They range in size from almost microscopic dimensions to masses 2 to 3 feet in width traceable for considerable distances along the strike. Veins of this sort were particularly examined at the head of Dahl Creek, north of Shungnak. At this place the hillside is covered with a heavy quartz float derived from veins in the vicinity, many of the pieces weighing more than 100 pounds. Although quartz was practically the only mineral recognizable in the rock, many specimens from this place in the possession of prospectors showed considerable free gold in well-formed crystalline aggregates.

Although the younger quartz veins are numerous in the harder, more resistant Paleozoic rocks, it is relatively uncommon to find them extending far into the limestones. It is believed that the reason for this condition is not that the higher rocks had not been formed, but rather that extensive fissures could not be maintained in a rock that flows under pressure so easily as a limestone. In other words, the more brittle rocks fractured and produced open spaces

when subjected to deformation, whereas the limestones yielded somewhat as wax does under pressure. This feature makes it uncertain whether a particular limestone was formed later than certain of the veins in near-by areas or not, and therefore in a large measure causes doubt as to the correlation of different members.

Before leaving the subject of the younger quartz veins it is necessary to point out that, although they were formed subsequent to the main period of dynamic metamorphism, many of them were subjected to pronounced mountain-building forces. As a result, although the veins are not so sheared and knotted as the older veins, they have been folded, faulted, and otherwise deformed from their original condition. They seldom occur, therefore, as continuous veins traceable for long distances with a constant dip and strike but are usually discontinuous, shattered, and irregular. This fact is important, for the development of mines on these veins will require a thorough and precise determination of the complex structural features of the veins to be exploited.

CALCITE VEINS.

Calcite veins are confined almost exclusively to the limestone areas and rarely extend more than a short distance into the schists. As a rule they are similar to the younger quartz veins of the gash type, and like them are believed to have derived their filling mainly from the rocks in the immediate vicinity of the fissures. Plate IX, *B* (p. 62), previously described, shows some of these calcite gash veins particularly well in the more massive member in the center of the view. At this outcrop, which is a short distance below camp August 4 on the Noatak, the longer axis of the elliptical cross section of the veins stands nearly vertical and the different veins are arranged en échelon.

Calcite is practically the only mineral in these veins. It occurs in many different forms, from separate crystals an inch or more in length, having perfect rhombohedral outlines and open spaces between the crystals on opposite walls, to fine-grained marble-like masses completely filling the vein. In a few veins a little quartz has been found associated with calcite, but it is generally in small amounts. Sulphides occur but sparingly in the calcite veins, though in some of the brecciated limestones there has been sulphide mineralization that is so associated with calcite that the rock superficially appears to be a calcite vein. Native gold is not known to occur in any of the calcite veins in the Noatak-Kobuk region. North of Nome in Seward Peninsula and in the vicinity of Chicken Creek in the Yukon-Tanana region gold has been found in calcite veins. It is not known whether the veins are similar in origin to those in the

Noatak-Kobuk region, but it is believed that as a whole the calcite veins of the gash type do not warrant exploitation as lodes and also did not afford any notable amount of gold for the production of placers.

ORIGIN OF THE VEIN MATERIAL.

The source of the vein material in the two types of veins known to carry valuable minerals, namely, the older and certain of the younger quartz veins, is as yet undetermined. So far no connection has been traced between any of these types of veins and the igneous intrusions. The absence of definite proof, however, does not preclude the possibility of such an interrelation. It is an important question to determine, for the distribution of the veins depends on the geologic history, which is therefore a matter that should be closely investigated in the field and the conclusions thoroughly tested.

The greenstones and associated schists show some sulphide mineralization of a disseminated type that may have been brought in during the intrusion of the rock from a deep-seated source. The amount of this mineralization, however, seems to be very slight. Sulphides are also found in intrusive rocks at the Noatak Canyon, but only in scattered grains, and the mineralizing effect does not seem to have extended far beyond the immediate contact. In the regions occupied by granite a little sulphide mineralization was observed. It was so small in amount, however, that save for a few scattered brown oxide stains on the rock it would have almost escaped detection. No sulphide mineralization in the recent basalts has been recorded.

It has already been suggested that the fillings of certain of the quartz and calcite veins which occur in irregular gashes have been formed during or at the close of the dynamic metamorphism of the region. In this type of vein it is believed that the filling has been derived from the contiguous rocks and has migrated into the open spaces where it has been deposited. If this interpretation is correct, it seems probable that these veins, though of widespread distribution, hold out little promise of being commercially valuable.

SUMMARY OF THE GEOLOGIC HISTORY.

From the preceding description of the various rocks and deposits that have been recognized, together with the notes on their structures and relative ages, the geologic history of the region may be inferred. However, as the reconstruction of these different stages in the history are not obvious to all, an attempt will be made in the following pages to give a consecutive statement of the various events that are believed to have occurred in the Noatak-Kobuk region. In this summary much of the evidence on which the succession has been

determined has been omitted and should be sought in the general descriptive portion of the report. In order to avoid too much repetition some of the statements have been made more definite than the facts at hand warrant; for instance, the Bergman group is regarded as Upper Cretaceous, though, as explained on pages 86-87, this determination is not proved by fossils nor exact stratigraphy but is based on several assumptions. The following statements should, therefore, not be considered independently from the fuller evidence presented in the earlier portions of this report.

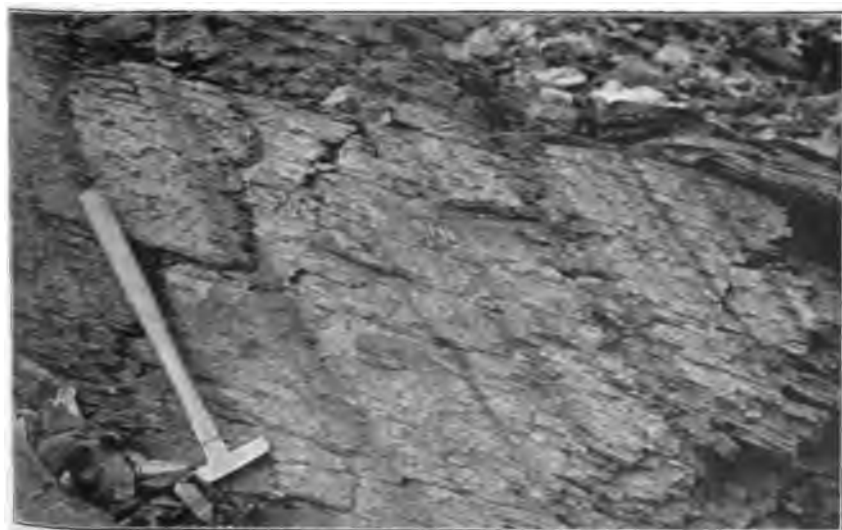
The earliest event recorded in the region was the deposition of certain of the undifferentiated schists as sediments probably similar in all essential respects to the sands and muds that are being deposited in the sea at the present time. Subsequently these deposits were consolidated, possibly undergoing various elevations and depressions so that occasional breaks in the depositional cycle may have occurred. Veins of the older quartz vein group were found in the rocks. A pronounced period of deformation then ensued, whereby the rocks were sheared and rendered schistose and secondary minerals formed. This mountain-built mass was then subjected to erosion, streams and other denuding agencies beginning to carry away material from the highlands and to deposit it again in the sea. After this process had continued for a considerable time the region was submerged and some of the undifferentiated limestones were deposited. Owing to uncertainty as to the age of these rocks, it is impossible to state the time of this depression and as there was probably more than one period of limestone formation the history of this part of the geologic sequence is obscure.

During the deposition of the earlier undifferentiated limestones there appear to have been igneous intrusions marked by the presence of the greenstones. These have been subjected to profound deformation and seem to be older than the main mass of the undifferentiated limestones and were formed apparently at the close of the early great period of mountain building. A period of greenstone intrusion has been recognized in many parts of Alaska—in Seward Peninsula, in the Koyukuk basin, in the Yukon-Tanana region, in the Copper River region, and in the Kaiyuh Hills. The evidence from these places does not afford conclusive proof as to the time of the intrusion, for in Seward Peninsula the greenstones cut limestones of questionable Devonian or Carboniferous age, in the Yukon region the greenstones are Devonian, and in the Copper River region and in southeastern Alaska the intrusion was Carboniferous or later.

In the Mississippian the region was again one of deposition and the Noatak sandstone and Lisburne limestone were laid down. The fossil contents of these two formations show that the rocks were



A. DOUBLE STRUCTURE IN LIMESTONES, NOATAK RIVER



B. DOUBLE STRUCTURE IN SANDSTONES, NOATAK RIVER.

essentially contemporaneous, but the deposition continued for a long time, as is shown by the great thickness of strata composing these formations. The presence of Triassic float shows that deposition was more or less continuous into the Mesozoic. That there were interruptions is probable, for the Triassic is Upper Triassic and no Pennsylvanian nor Lower or Middle Triassic is known, so that the region may have been an area of erosion during that time.

After the consolidation of these sediments another period of mountain building ensued, in which these rocks, together with the earlier schists, were folded and faulted and probably lofty mountains were formed. Erosion again began to attack the region, to wear down the hills, to remove the materials and to form deposits in outside areas.

No records of the events in the middle Mesozoic are preserved unless portions of the Koyukuk group in the Zane Hills and the igneous rocks associated with the known Lower Cretaceous limestone were formed in this period. It has already been suggested that from analogy with other parts of Alaska such an assumption is reasonable, though unproved. Following the early basic effusives and intrusions there were widespread injections of granitic rocks.

In the Lower Cretaceous the only definite fact is that limestones were deposited. Fragmental volcanic ejecta and flows are apparently closely associated with these rocks. As may be judged from the geologic history of near-by portions of Alaska, pronounced deformation and further volcanic effusion closed this period. This resulted in a considerable part of the region becoming land subjected to erosion. The material removed from this land was deposited in the sea that probably existed south of the Kobuk. Gradually the region sank and the Upper Cretaceous deposits encroached farther and farther on the land, possibly extending continuously from the southern to the northern margin of the mapped area. Thousands of feet of strata were deposited during this period, which probably extended from the Upper Cretaceous into the Eocene.

With the close of this period of deposition the last great period of deformation ensued. The present major topographic features were produced, though the mountains were probably much more lofty, and the details were far different from those seen to-day. Probably it was during this period of mountain building that the already folded Mississippian rocks were still more deformed, and the secondary structures, such as those shown in Plate XIV, may have been produced. The absence, however, of evidence concerning the relations of the Cretaceous and Mississippian makes the time of formation of the cleavage indefinite, and it is possible that the latest structure shown in these views was produced during the post-Mississippian deformation noted above.

From that time on the region has been land and has been undergoing almost continued erosion. The only marked interruption to this process was the effusion of the recent basalts, which probably began late in the Tertiary and extended down almost to the present. These effusions appear to have been spasmodic and to have taken place in a number of separated areas. The lavas flowed into the lowlands of the existing topography and by their resistance in many places have preserved these surfaces from further erosion until the lavas themselves had been removed. It is for this reason that many of the characters of that old land surface may be determined by the scattered patches which in favorable localities have been preserved under the lavas.

While the lavas were being poured out in the lowlands, erosion was still active over much of the area, and the highlands were being more and more degraded. Movements of the earth's crust without doubt also took place, but these were broad regional uplifts or depressions rather than sharp mountain-producing flexures.

After erosion, deposition, and lava effusions had been in progress for some time, a change ensued whereby glaciers were formed in the mountains. Many of these glaciers were large and extended for considerable distances down the previously formed main valleys. So far as known, however, all of them were distinctly of the valley type, and they did not form huge ice caps mantling all the country, as did some of the now vanished ice sheets in the northern United States. To these ancient glaciers must be attributed the formation of many of the most prominent of the present-day erosional and depositional features.

Concerning the late geologic events, the following account of observations in southeastern Seward Peninsula¹ gives a general idea of the conditions observed in the Noatak-Kobuk region:

All this time deposits of glaciofluvatile, fluvatile, and marine origin were being formed in the areas not occupied by the ice, where the conditions were favorable. Lava flows may also have occurred at this same time in the areas not occupied by the ice.

With the close of glacial conditions oscillations of the crust similar to those preceding the period of glaciation again become evident. It is not intended to imply that these oscillations ceased during glacial time, but the evidence is so obscured that the movements were not recognized. The general result of these postglacial uplifts has been to raise the region somewhat above the relative position it occupied during the Pleistocene. Apparently, however, the sum of the recent upward movements has not yet equalled the sum of the earlier downward movements, so that the floors of many of the larger streams are still below sea level. The general recent uplift is shown in the rock-walled shallow canyons in which many of the streams flow.

Although the later Tertiary to Recent movements have been described as resulting in certain general conditions, it should be distinctly understood that these move-

¹ Smith, P. S., and Eakin, H. M., *op. cit.*, pp. 99-100.

ents were such that while depression was taking place in one part of the region, uplift may have taken place in another. Hence it appears that deposits at the same elevation above or below sea level are by no means synchronous and may be entirely unrelated in origin. Contemporaneity of the various deposits can only be determined by careful and detailed investigations of the region. Inasmuch as many of the problems of economic importance are connected with the correct correlation of the different deposits, it is necessary that such correlations should be searchingly investigated and not be based on superficial examination or upon apparent similarity of factors known to be variable.

ECONOMIC GEOLOGY.

GENERAL FEATURES.

The larger part of the Noatak-Kobuk region is unexplored, and even in places that have been visited by prospectors and miners little is really known about the mineral resources. In spite of this fact gold placers, gold and copper lodes, and deposits of nonmetalliferous minerals, including coal, have been found and partly developed. These deposits occur in many parts of the region that have been studied by Survey geologists. It is proposed to set forth in these pages the facts learned about the different occurrences and the suggestions and inferences drawn from them as to the conditions under which the deposits were formed. It is believed that in this way the record will be of service not only in describing the present status of the mining industry but also in pointing out the places where further prospecting or exploration is likely to bring returns and in indicating areas that are dissimilar to the known productive regions. In this description the northern part of Seward Peninsula, included on the geologic map (Pl. II), will be omitted, for the mineral resources of that region have already been treated in a publication of the Survey by Moffit,¹ which should be consulted by those interested in that district.

GOLD PLACERS.

KOBUK BASIN.

GENERAL CONDITIONS.

Auriferous gravels have been reported in many parts of the Kobuk basin, but in only two regions has there been any notable production—the Shungnak region in the central part, and the Squirrel River region in the western or lower part. Mining in the Shungnak region has been carried on almost continuously since 1898, but in the Squirrel River region the discovery of placers was not made until the fall of 1909. There are geologic grounds for believing that much of the area between these two camps may subsequently prove to contain auriferous deposits. The economic conditions imposed by the geo-

¹Moffit, F. H., *The Fairhaven gold placers, Seward Peninsula, Alaska*: Bull. U. S. Geol. Survey No. 30, 1906.

graphic position of the Kobuk region, however, have exercised and must always exercise a control that will prevent working deposits which in a milder climate and in more accessible regions could be successfully mined. Although it is probable that the present high costs may be in part decreased as the region becomes more opened up, the long distances that supplies must be carried, the frequent handling of freight required, and the short season available for water transportation and surface mining are unavoidable.

The general geologic conditions in both the Shungnak and Squirrel River regions are similar. In the former region glaciation was much more pronounced in the past and it undoubtedly affected placer accumulations to a more marked extent. The area of the more mineralized rocks is less in the Shungnak region, but the lower part of the Squirrel River region is more extensively covered with outwash deposits. At both localities the gold in the placers appears to be near its bedrock source and seems not to have been transported far. As a result the rich ground is more or less irregularly distributed and the tenor ranges within wide extremes.

SHUNGNAK REGION.

The main placer developments in the Shungnak region are on those streams heading in or flowing through the Cosmos Hills, namely, Dahl Creek; Riley Creek, a tributary of Kogoluktuk River; and Shungnak River. When visited in 1910 there were only 10 to 12 miners in the whole region, so that the production was small. Although no accurate statistics are available as to the production, it is doubtful whether \$100,000 in gold has been taken from the placers in the 10 to 15 years that they have been worked.

DAHL CREEK.

Dahl Creek is a stream 8 miles long, the lower 3 miles or so of its course being through the Kobuk lowland, the middle 2 to 3 miles in a narrow rocky gorge, and the upper mile or two in a rather open valley. The placers that have been worked are located near the southern face of the Cosmos Hills and in the central part of the valley, where the junction of three small streams with Dahl Creek has made a small flat. During the time that the Survey party was in the region no work was in progress on any of these claims, but mining had been carried on earlier in the season at both places, and had been in progress for several years in the past.

The bedrock under the unconsolidated deposits here is black slate and schist with numerous small veins of quartz and in places some sulphide mineralization. The bedrock breaks into rectangular blocks of small size and the joint faces are commonly iron-stained. The

dominant strike is across the creek, and thus the rocks make good benches for catching the gold. The slope of the bedrock surface is rather low, so that some difficulty is experienced in disposing of the shales from mining. Near the lower group of claims schistose conglomerate outcrops but does not form bedrock under the productive placers. Limestone occurs near the placer ground in the middle part of Dahl Creek, but although float from this rock is found in the gravels it does not come down as far as the creek and does not form any of the surface on which gravel accumulation took place. Igneous rocks of a dense texture and greenish, glassy color were noted upstream from the placers, but though these rocks have furnished many of the boulders in the placers, they do not seem to have been connected with the mineralization and did not contribute valuable minerals to the placers.

Only the creek gravels have been mined on Dahl Creek. These average about 4 feet thick. In some places their thickness is only a foot or so, but in others it is as much as 8 feet. Holes sunk on some of the low benches on either side of the stream have shown unconsolidated deposits 15 feet thick. Practically none of the stream gravels are permanently frozen, but some of the low benches that have been prospected are reported to be in that condition.

The gravels in the productive placers are of the normal creek type, consisting of well-rounded pebbles with only a small amount of muck. Large, somewhat angular boulders, most of which are of local derivation, are numerous in the gravels and cause a good deal of trouble in the mining operations. One of these large boulders a short distance below the placers, near the southern face of the Cosmos Hills, measured 14 feet in length. It was made of the sheared conglomerate and had not been transported far. Many smaller boulders occur directly in the pay gravels, however, and it has been necessary to blast them out of the way.

The pay gravels differ in no essential respect from the overburden. They are usually from 1 to 2 feet in thickness and practically all the gold lies in and on the bedrock. The distribution of the auriferous gravels is very irregular and it has been impossible to successfully trace any continuous pay streak. The gold occurs in pockets, which, when exhausted, give no clue as to their relation to other rich spots. Such a distribution seems to indicate that valuable minerals were either laid down more or less evenly and then dispersed by a change in the discharge of the creek or else that the gold was originally deposited by a stream having strong variations in transporting ability.

Owing to the irregular distribution of the gold the value per cubic yard is of almost no significance. When a rich spot is found several

hundred dollars may be taken out in a few days, but at other times only a dollar or so a day can be made. Figures for the total production are also unsatisfactory, but they give a more accurate estimate of the value of the ground. The returns are not complete and probably exaggerate the amount of gold recovered, but they are an indication of the size and present importance of the creek. According to the returns of the miners, in no year has Dahl Creek produced more than \$10,000, and probably half this amount is nearer a correct estimate for the average production during the past six years. If this assumption is correct, not over \$30,000 has been taken from this creek since its discovery.

Only a small amount of Dahl Creek gold was studied, so that a full description is not available. The gold examined from the upstream group of placers was reddish to brass-yellow in color. The pieces were small and some were distinctly spongy and had fairly sharp outlines, as though they had not been transported far from their place of origin. Some wire gold was also seen but was notably rare. Nuggets of considerable size have also been found in this part of Dahl Creek. One of these was seen that had a gold content worth about \$65. It was a fairly well-worn piece and had a considerable amount of greasy-looking milky quartz attached. In 1911 a large flat piece of gold worth over \$600 was found near this place. Assays are reported to have shown the gold to be worth about \$16.20 an ounce.

Among the concentrates from Dahl Creek placers magnetite is the most abundant mineral. There is also a small amount of chromite, some of the pieces being a foot or so in diameter. Garnets are almost entirely absent. The occurrence of native silver in the concentrates has been reported and pieces nearly an inch in diameter have been examined. The silver seems to be particularly free from admixture with other metallic minerals, such as copper or lead; a small amount of cadmium, however, was recognized by blowpipe examination. No evidence was secured as to the source from which the silver was derived.

Mining is carried on by pick-and-shovel methods and the gold is won by passing the gravels through sluice boxes of whipsawed lumber. Owing to the high transportation charges machinery would be expensive to install, and owing to the character of the gravels and their tenor few mechanical devices could be successfully operated. Short ditches provide the necessary head for sluicing, and there is almost always sufficient water to meet the demand.

From the physical features of the gold and the distribution and other characters of the auriferous alluvium it seems probable that the gold has been derived from places within the Dahl Creek basin, espe-

dally from the areas occupied by the black slates and schists. It is believed that the source of the mineralization is the quartz veins, which are so abundant in this formation.

Some prospect holes have been sunk near Dahl Creek close to the southern front of the Cosmos Hills or the northern margin of the Kobuk lowland. The returns have, however, been insufficient to warrant development and the holes have been allowed to cave, so that it was impossible to examine a section of the gravels. It was reported by prospectors that the bedrock surface slopes southward at a high angle below the lower cabins, so that shafts even 40 feet deep failed to reach bedrock. In this lower part of Dahl Creek the stream flows through the unconsolidated deposits of the Kobuk lowland. The absence of any shallow placers in this part of its course seems to indicate that the upper part of the gravels of the lowland area does not contain sufficient gold to form economic deposits where subjected to the sorting of such streams as Dahl Creek.

KOGOLUKTUK RIVER.

Sparsely disseminated colors of gold have been reported from many parts of the Kogoluktuk basin, but the only stream on which placers have been mined is Riley Creek. This is a tributary from the west, heading against the Dahl Creek divide and flowing first north, then east, to join the Kogoluktuk. Placer ground has been mined in a desultory way by parties of one to three men on the headwaters of this stream since 1908. Mining was in progress here when the region was visited by members of the Survey in the early part of August, 1910, but soon afterwards was abandoned for the season.

The placers occur in a region of black slates, limestones, and a few intrusive igneous rocks. The bedrock is similar to that of the placers on Dahl Creek, except that limestones are much more numerous. Evidences of deformation and dislocation are pronounced and the stratigraphic succession of the rocks has not been determined. Quartz veins in the black slates that form the bedrock under the ground that has been worked are particularly numerous and are believed to be closely associated with the formation of the productive placers.

In the placers typical stream gravels are practically absent. Sections show angular slide and slightly worn unconsolidated deposits of local origin in which are irregularly distributed boulders from outside basins. Most of these foreign boulders are of large size and are mainly of igneous rocks belonging to the greenstones and associated types. They are usually well worn and probably have been brought into their present position by the combined action of ice and water during the closing stages of the glaciation of the lowland

north of the Cosmos Hills. Although these greenstone boulders are found in the placers, they are in no way connected with the origin of the gold, and their distribution, except as marking former glacio-fluviatile-conditions, is of no economic significance.

The gold occurs mainly in the crevices of the bedrock and in the angular unconsolidated material lying on top of the bedrock. In the part of the deposit that is mined large boulders are less numerous than in the upper 2 or 3 feet, but there are many boulders even in the pay streak. The whole character of the material in which the gold is found is more like that of residual placers than of ordinary creek placers.

The slight amount of transportation that the auriferous material has undergone is also indicated by the shape and quality of the gold. Practically all the pieces examined were sharp and angular and many had small particles of quartz attached. No large nuggets have been reported from these claims. Pieces worth up to 50 cents were seen, and a few worth as much as \$2 to \$3 were reported. The gold was bright and in an average sample the pieces were worth from one-tenth cent to 2 cents each. The individual particles are spongy and consequently appear to one used to the usual run of placer gold to be worth much more than is actually the case. The precise assay value of the gold was not learned, but it was understood to be about \$16.25 an ounce.

Accurate estimates of the total production are not available, but from the amount of ground that has been mined during the past three years and its reported tenor it is believed that not much more than a thousand dollars a year in gold has been won.

Mining costs are high and the Riley Creek placers are unfavorably situated for economic development. The two greatest obstacles to cheap mining are absence of a sufficient water supply and the presence of large boulders. The latter trouble, however, is not so serious as the lack of water, for few of the boulders are so large that they can not be rolled out of the way by hand or be gotten rid of by undermining. Practically the only water available is derived from the melting snow on the north-facing slope of the Dahl-Riley creek divide. Furrows parallel with the contour have been dug on the hill slope to collect the surface and shallow seepage water formed from the melting snow banks. From these furrows the water is led down the hillside and impounded behind a sod dam, whence it is led by a short ditch and hydraulic hose to the sluice boxes. So slow is the collection of water that under favorable conditions it takes about $3\frac{1}{2}$ hours to collect enough for $1\frac{1}{2}$ hours sluicing. No water, of course, can be wasted for groundsluicing. Even shoveling into the sluice boxes can only be carried on for four or five periods a

day. During wet weather, of course, the reservoir fills up more rapidly and so relatively longer periods of sluicing are possible.

After the period of sluicing and while the dam is refilling the miners are busy cleaning away the large bowlders and getting everything in readiness for the next time that the water can be turned on. The large bowlders are not cleaned but are simply rolled onto the already worked out part of the claim. In order to use the water effectively, the sluice boxes are made only about half the ordinary width and were formerly set on a pitch of 1 inch in 12 inches. Subsequently, however, a pitch of 1 to 15 was adopted.

The Riley Creek placers that have been worked seem to derive their gold content from the rocks exposed in the immediate vicinity. They are so situated that they have no adequate water supply and bowlders are so numerous that the placer can be developed only at great expense. Farther downstream, where the water supply might more nearly meet the demands, the presence of thicker overlying deposits and large bowlders is to be expected. The absence of especially effective sorting in this part of the basin suggests that placers will be of distinctly local importance. The whole Kogoluktuk basin, so far as indicated by the conditions on Riley Creek, seems to promise only localized placers of irregular distribution, workable as pockets rather than as extensive deposits.

SHUNGNAK RIVER.

Placer mining on Shungnak River has been carried on for a mile or so below the narrow canyon by which this stream traverses the Cosmos Hills. Work has been in progress here during the open season almost uninterruptedly since 1898. Only two or three parties of three or four men each have attempted mining during any year, and in 1910 only one placer camp of one white man and two or three natives was in operation. The use of native labor is an interesting experiment and, although it is reported that white men can do more work, the wages paid the natives (about \$4 a day and board) are so much lower that the difference in efficiency is compensated for.

Bedrock in the productive part of the river is mainly black slate and schist, but other sedimentary and igneous rocks occur at no considerable distance from the placers. Limestones occur near the head or northern end of the canyon, but are not closely associated with the deposits of auriferous alluvium. The igneous rocks near the placer mines are composed mainly of serpentine with scattered particles of magnetite and are of a dark-green color. These rocks have been sometimes mistaken for jade, and it is probably owing to this error that the whites have reported the name "Shungnak" to mean "jade" in the native language.

Most of the mining has been done near the southern face of the Cosmos Hills, where small flats permit turning the stream aside by wing dams. The gravels mined are usually shallow. The upper two feet or so is stripped off and the lower part only is put through the sluice boxes. The overburden is made up of typical river gravels with some large boulders irregularly distributed throughout. It is not known whether the valley of Shungnak River through the Cosmos Hills was at one time occupied by ice, but it is certain that glacially eroded and transported boulders have been brought in by glacio-fluviatile action and form part of the reworked material of the unconsolidated deposits.

The pay gravels are rather irregularly distributed and mining therefore has been in the nature of pocket hunting in those places where the water could be handled. The gravels are unfrozen and in a measure this is a disadvantage, as much water seeps into the pits. During high water the miners are sometimes driven out of the workings. The gold is found in the lower part of the unconsolidated deposits and in the crevices of bedrock, especially where it is black slate.

Most of the gold found in the placers of the Shungnak is in small pieces worth from one-half cent to 3 cents, but nuggets worth up to about \$40 have been found, although they are by no means numerous. The gold is reddish, and although not rusty it is not bright and shiny but has a dead luster. Its assay value is reported to be \$16.70 an ounce. The form of the gold is very characteristic and is distinct from that of the gold from any other part of the Shungnak region. The little pieces look like shot that have been flattened under the hammer, and this form is sometimes spoken of by the prospectors as "pumpkin seed" gold.

Magnetite is by far the most abundant mineral among the concentrates collected with the gold and is probably derived from the basic intrusive dikes which cut the metamorphic rocks. Garnet, or so-called "ruby," is almost entirely absent from the gravels. Small nuggets of copper and also of silver are sometimes found in the sluice boxes. Some of the silver nuggets are nearly an inch in diameter and contain but very small amounts of other metals as impurities. No clue as to the origin of the silver was obtained, but the copper nuggets were probably derived from the copper sulphide impregnated zone near the limestone-schist contact, an example of which will be described in more detail on pages 147-150.

Statistics of the production from the Shungnak River placers have not been kept and estimates prepared by interested parties are not reliable. It is improbable that the annual production amounts to more than a few thousand dollars in gold, and a liberal figure for the total production from this river would not be more than \$50,000.

SQUIRREL RIVER REGION.

DEVELOPMENT.

The developments in the Squirrel River region have been small, and although gold prospects are said to have been found on eight to ten tributaries, when the region was visited in 1910 mining was in progress on only one of the streams, namely, Klery Creek. That this is the only place where productive placer exists is improbable, for conditions analogous to those on Klery Creek are reported at several other places in the Squirrel River basin. With further prospecting other valuable placers will undoubtedly be found. There is, however, the strong tendency of prospectors to hold ground on a proved creek and to prospect the adjacent areas only when driven to it by the exhaustion of the known ground or the inability to secure claims in the desired creek.

At the time the region was visited by the Survey geologist not over 50 men were at work, and about a third of this number were employed on one claim. Capital had not taken hold of the region and there were few opportunities to work for wages; consequently the camps were run on a partnership basis and few of the men were equipped with the supplies necessary to carry them for a year or so of unproductive labor, such as that involved in building drains for opening up a property. Wages were said to be \$7.50 a day and board for ordinary miners, but as there was only one company employing men and as that company was able to obtain all the help it needed at \$5 a day the above figures are more or less fictitious. Though the labor conditions will undoubtedly change if the camp proves successful persons should be warned against going to Squirrel River if they have nothing but wages to depend upon. In 1910 there was no chance of employment for more than a few men, and without supplies or funds any venture would be unsuccessful.

Furthermore, the usual wholesale staking of the region has tied up much of the available ground, so that unless the prospector goes some distance from the productive creeks his chance of obtaining a claim by original location is slight. One is compelled to go a considerable distance from the proved ground or else buy or obtain a claim on a recorded claim. Any of these choices entails additional expense, which the prospector should be prepared to meet. The unjustness of the system is well shown on Klery Creek, where 64 claims have been recorded above the Discovery claim and at least 20 below that point, and yet there is no work being done on more than ten of the claims and of these probably not more than four or five produced a thousand dollars during 1910. This statement is not intended to discourage prospecting but only to point out the small amount of work really in progress.

The sketch map shown in Plate XV, compiled mainly from reports of prospectors, shows the eastern part of the Squirrel River basin. Although it has not the same degree of accuracy as the other map accompanying this report, it shows the general arrangement of the streams, the approximate distance and direction between places, and the areas where auriferous gravels have been discovered.

CREEK PLACERS.

Description of operations.—Klery Creek was the only stream on which mining was in progress in 1910, and as two or three claims on this stream were seen in detail a description of its placers will be given. It should be borne in mind that the general conditions at the placers where mining is being done are likely to be the same at similar places throughout the field, so that the facts learned by mining on one claim are helpful in the understanding of unprospected ground.

The most active work was in progress near the mouth of a small tributary, Jack Creek, a short distance above the Discovery claim. At this place there is a rock-cut gorge with a gravel-covered floor about 150 yards wide. On this floor the stream formerly followed the eastern side, but in order to allow mining the stream was turned to the other side by a roughly constructed dam. Owing to the exceptionally rainy season of 1910 the stream was abnormally high, and three times during the summer the dams were completely washed away by the floods, some of the sluice boxes with the gold in them being recovered only with difficulty. The upper 12 to 18 inches of gravel in the bed where the stream has been turned aside is removed by shoveling and the larger boulders are either rolled behind the miners onto worked-out ground or are pulled out of the way by a team of horses. This stripping is done rapidly and is carried down to a point where the gravels show some "sediment" or fine mud that coats the well water rounded pebbles and fills the interstices. None of this surface material is put through the sluice boxes, as repeated experiment has shown that it contains practically no gold. Between the upper foot or foot and a half of gravel that is stripped off and bedrock is a foot to a foot and a half of gravel in which gold is obtained. These gravels are typical river wash, but have been less recently handled by the stream than those above them. The lower gravels, together with the upper 6 inches to 1 foot of disintegrated bedrock, are put through the sluice boxes and it is from them that the gold is won.

Bedrock on this claim is mostly schist, but on the lower end of the claim and continuing downstream on the next adjacent claim is a massive, much-fractured, and contorted bluish-white limestone standing at a high angle and cutting the country transversely. The

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schist shows many different phases on the working claim. In part it is a dark graphitic slaty schist with numerous small veins and stringers of quartz. The bands of this schist are not more than a few feet in thickness and are interlaminated with somewhat calcareous and quartzose schists, some of which are rusty yellow in color owing to the decomposition of some of their constituents. The iron mineral from which this limonite had been derived could not be determined, but it was probably in part pyrite. In at least one place on the claim a narrow band of limestone interlaminated with the schist was seen. From this description of the bedrock it is evident that lithologically the rocks are similar to those in the richer parts of the Nome region, in the Iron Creek basin, in the Kougarak, on Ophir and Melsing creeks near Council, in the Solomon and Casadepaga regions, and near Bluff. This resemblance is further strengthened by the relation of the schists to the heavy bluish-white limestones at all these places.

Several hundred ounces of gold from this claim were examined and the coarseness of the pieces was remarkable. Practically no fine gold was found and few if any pieces of the gold recovered were worth less than one-half cent. Several nuggets worth \$25 to \$50 have been found, and while the writer was on the ground one nugget weighing nearly 7 ounces and worth about \$125 was picked up in the gravel. In form the gold from this claim is chunky or in nuggets, but a little wire gold was also seen, though no flaky or scaly gold was observed. The gold is dark, but almost never black, and shows few signs of recent movement. Although some of the corners have been rounded, it does not in general appear to have traveled far. In fact, many pieces are sharp and angular as though but recently unlocked from the parent ledge. Some of the nuggets have pieces of the country rock still adhering to them. The most abundant mineral attached to the gold is quartz of the same physical aspect as the quartz in the stringers and lenses in the schist. Black graphitic slaty schist is also attached to the gold in some of the specimens, and the way in which the gold forms filaments in this rock shows indisputably that some of the placer gold has been derived from this kind of country rock.

Estimates of the productiveness of this ground are of small value, for the nuggety character of the gold makes the tenor range between wide limits. It is reported that over 190 ounces were cleaned up from about six box lengths shortly before the visit by the Survey geologist. At the time of the writer's visit a clean-up of 120 ounces was made from about 4½ box lengths. This is equal to a bedrock surface of about 500 square feet, so the production from this cut was nearly \$4.50 per square foot of bedrock. As a working force of 15 men were able to strip and shovel into sluice boxes this amount of ground in a little over a day, it is evident that this work is immensely

profitable. The width of the pay streak is not known, for when the claim was visited all the work had been done only on the eastern side and the western margin of the productive ground had not been reached.

Water for sluicing is obtained from Klery Creek by running a hydraulic hose several hundred feet upstream and bringing down the water thus obtained on as flat a grade as can be maintained. This supply, however, does not furnish an adequate head, so that some other method will have to be tried. But slight difficulty should be experienced in obtaining a satisfactory supply, as the volume is ample for the present demands. No accurate measurements of the volume of Klery Creek were made, but the fact that a crossing, even on a riffle, could not be made in less than $2\frac{1}{2}$ feet of water, in a current of such speed that care had to be taken in keeping one's feet, shows that several thousand miner's inches are probably available during a season such as 1910. It should be noted, however, that that year was abnormally wet and estimates based on observations during that time are undoubtedly above the average.

Few assays have been made of gold from this claim, but on a sample submitted to the assayer of the Nome Bank & Trust Co. a fineness of 0.888 $\frac{1}{2}$ was determined. This would give a value of \$18.37 an ounce.

In the concentrates collected with the gold in the sluice boxes magnetite is the most abundant mineral. This forms a much larger proportion of the concentrates than it does around Nome. Together with the magnetite is also some ilmenite and a little pyrite and limonite. These iron minerals are probably derived mainly from the greenstones and greenstone schists, although the pyrite and its accompanying limonite may have come from veins in the schists or from the vicinity of the limestone-schist contact, a place commonly mineralized in other regions. Garnet or so-called ruby, common in the concentrates from Seward Peninsula, is relatively rare and forms but a small proportion of the black sand. This mineral is absent in the adjacent schists derived from igneous and sedimentary rocks. None of the rare heavy minerals so far have been recognized in the concentrates.

About $1\frac{1}{4}$ miles upstream from this claim is another claim where gold similar in physical character has been found. Work on this ground has been carried on by a crew of only four men and consisted mainly in dam building and bringing up a bedrock drain, so that only a small production had been made and the opportunity of examining a large amount of gold was not afforded. It seems certain, however, that the gold from this claim is of the same chunky character as on the lower claim, although the proportion of fine gold is larger and the nuggets, as a rule, weigh less. From the shape of

gold it is believed that it has been derived from near-by sources and has not traveled far.

Midway between these two claims the gold is of an entirely different character, although the general geology shows no marked change, except that the limestone is more remote and the canyon character of the valley is more pronounced. The gold from this claim is practically all in fine bright scales. No nuggets worth more than a few cents each have been recovered, though several hundred dollars' worth of gold has been won. The scales are all more or less of the same size, no flour gold being seen. All of the flakes are of a bright gold color with no tarnished nor black coating. No pieces with quartz or other foreign material attached were seen. This gold was of the type locally known to the miners as "bar" gold and showed by its physical characters that it has traveled much farther from the ledge from which it was derived than that found either upstream or downstream from this place.

Gold similar to this "bar" gold has also been found downstream from the first-described claim. It is identical in all essential respects with the one just described and has probably had a similar history. The fact that this gold has traveled farther from its parent ledge is indicated by its higher assay value. It is not possible to give the precise assay value, for the sample that was tested was mixed with nugget gold taken from one of the claims farther upstream. This mixed sample, however, showed a higher gold tenor than the nugget gold previously quoted as worth \$18.37 an ounce, so the difference is probably to be assigned to the greater fineness of the "bar" gold.

Origin of the gold.—The distribution of the gold and the difference in the physical characters presented by this mineral from the several claims in this stretch of about 2 miles present problems of economic importance. It is believed that the coarse nuggety gold on the two claims has been derived from near-by areas of bedrock and has not traveled far from its source of formation. Possibly concentration had been effected in earlier stages of the valley development, and the gold was subsequently reconcentrated in the present streams, but the movement by this process must have been relatively slight. On the other hand, the fine flaky gold found downstream from the areas of coarse gold seems to represent the smaller, lighter particles which, because of their size, have been carried farther from their source. Such an interpretation is analogous to the well-known distribution of gold in a sluice box, where the larger, heavier particles are found toward the head end of the box and the smaller, lighter pieces near the foot or discharge end. According to this explanation there are several localities of mineralization cut by Klery Creek, each being more or less close to the areas of heavy gold, whereas in the

intermediate regions the stream has not been so close to regions of as great mineralization and the gold has been derived from the areas upstream.

Too little is known about the region to determine beyond question whether the mineralization is confined to a single zone or whether there are a great number of these mineralized zones, but from the number of places where gold has been reported in the Squirrel River basin it seems probable that there are at least several and possibly many zones of mineralization. Further study of this important question is necessary, for it affects the future of the region. Not only is it important in determining the probable area in which gold placers may be expected, but the information is also valuable in determining the trends of the placer ground. From the experience in Seward Peninsula it is believed that the contact of the heavy limestone and the graphitic or quartzose schists is one of the most favorable localities for searching for placer deposits in this group of rocks. This experience seems to be borne out in part by the work on Squirrel River, for the richest claim so far discovered has been near this contact. That there are other places where mineralization has been pronounced can not be doubted, and the prospector should therefore not place undue emphasis on the above suggestion.

BENCH AND DEEP GRAVELS.

So far only the shallow creek gravels in the stream beds have been exploited. There are, however, bench and high-level gravels in this region, as well as the broad fillings of the main stream valleys, which are possible sources of mineral wealth. None of these older gravels have been prospected as yet, and therefore suggestions as to their probable value or character are tentative and subject to revision when more information is obtained. The lower benches already noted as occurring at several different elevations above the tributary streams, such as Klery Creek, seem to have had essentially the same method of formation as the known auriferous creek gravels. It is therefore believed that in the neighborhood of bedrock mineralization these benches will be productive of placer gold. Most of the benches of this character on Klery Creek had but small length or breadth, so that only discontinuous deposits resulted. Such benches, however, may afford rich pockets of auriferous gravel which would well repay exploitation. Many of the benches seem to be covered with muck and turf, which fact suggests that the gravels will be frozen and require thawing apparatus.

The higher gravels, which are of wide extent and cover not only the lower slopes of the Squirrel River basin but also extend both up and down the stream along the Kobuk, present problems that are much more difficult to interpret. The origin of these gravels can be solved only by a general survey of a large area in the lower part of

the Kobuk Valley, supplemented by numerous good sections of the deposits by means of prospect shafts. The character and distribution of these high-level gravels strongly suggest that they have not been formed by normal fluvial action. There is a possibility that they may mark marine deposition, but it seems more probable that they are the outwash deposits from ancient glaciers which at one time occupied the more eastern part of the Kobuk Valley. If this interpretation is correct, there is small probability that economically profitable placers will be found in these gravels. Although outwash deposits may contain gold, it is believed that normally the valuable minerals are so disseminated that, except under conditions of subsequent concentration, the valuable minerals cannot be profitably extracted. These high-gravel plain deposits consist largely of rolled quartz pebbles. No striated fragments or other marks of direct glaciation were observed. The condition of these gravels with respect to frost is not known. As a rule, gravel deposits at any considerable elevation above the adjacent streams are so well drained that they are not permanently frozen. At several places where these gravels are exposed in the valley walls of the tributary streams there are indications that they are not frozen. These places, however, are not conclusive as to the conditions of the gravels in the intermediate area between two streams, where the gravels are not exposed to the light and air and where the groundwater level rises so that the gravels are not as well drained. From the character of the surface in some of these less well-drained areas it seems certain that permanently frozen ground will be encountered.

No prospecting of the deeper gravels that form part of the flood plain of the main Squirrel River has been done, so that no definite information as to the presence of placer ground is available. It is understood that prospectors have found colors of gold on many of the bars and in shallow holes which did not reach bedrock. The ground was frozen and the necessary machinery for exploring the deposits was not at hand, so that the deep ground was abandoned for the more easily worked shallow creek diggings. From the experience on Seward Peninsula it seems questionable whether important placer gold deposits will be discovered in these flats. It should be reiterated, however, that the data for basing a decision are inadequate, and the above suggestion is little better than a guess, warranted only by the desire to prevent the reckless expenditure of time and money on ill-considered projects.

NOATAK BASIN.

EXTENT OF PROSPECTING.

There are no placer mines in operation in the entire Noatak basin. During the rush to Alaska following the gold excitement of 1898 the basin was visited by prospectors. None of the early nor the later

comers, however, discovered deposits of sufficient promise to tempt them to attempt development, and when the region was visited in 1911 even prospecting had practically ceased. Here and there in the lower 200 miles of the river abandoned cabins were seen which had been the homes of these gold seekers. A short distance below the Noatak Canyon was seen one of these cabins that had been abandoned but recently. A well-worn trail led to a near-by creek and there were evidences that placer prospecting had been in progress rather recently, but no information concerning the results of this work could be obtained.

Although it is doubtful whether more than a few hundred dollars' worth of gold has been mined in the entire basin it is believed that the region has not been adequately prospected. Numerous stories of rich finds indefinitely located are of course heard, but there are only two places where placer gold is known to have been found. These are in the headwaters of the river on Lucky Six Creek and near Midas Creek in the vicinity of the camp of August 2. The few facts regarding these two areas are given in the following pages.

LUCKY SIX REGION.

Lucky Six Creek is a stream joining the Noatak from the east about 12 miles in an air line south of the camp of July 23 at the mouth of the tributary of the Alatna heading in the pass to the Noatak traversed by the Survey expedition of 1911. Gold was discovered on this stream in 1898, and from time to time since then small parties of prospectors have visited the region. This place is so inaccessible, however, that the miners have spent only a few days there. Not only is the region inaccessible, but it is also difficult to prospect for lack of timber. It is reported that the planks used for making sluice boxes were whipsawed by hand on Reed River of the Kobuk basin nearly 30 miles away and were hauled by dogs and men to Lucky Six; there were no logs for cabins and consequently the prospectors lived in tents. Although now that more of the geography and resources of the region are known, it has been found that spruce can be obtained in the Alatna Valley not more than 12 miles in an air line from Lucky Six Creek, yet the labor of transporting the lumber even this distance and over a divide at least 1,000 feet high is a great tax on time and energy. Even wood for fuel is scarce and is mainly green alder and willow.

The Lucky Six basin was not surveyed, but the general geology was learned from a study of the stream to the north. This creek, known as Twelvemile Creek, is not more than 10 or 12 miles long. For half a mile or so above the mouth the stream meanders on the outwash gravel plain of the main Noatak. Farther up, the stream enters the hills and the river lies in a narrow precipitous gorge incised

bedrock and early glacial deposits. In this part the creek is not more than 50 feet wide, even during times of high water, but it is a roaring torrent with its bed full of huge bowlders that make crossing difficult. Still farther up, the gradient of the valley decreases, but in the headwater regions the slope again increases.

Geologically the Lucky Six region presents many problems. Various kinds of rocks occur in intricate relations. The larger part of the bedrock appears to have originally been a sediment that was subsequently metamorphosed. No masses of the granite were seen in place, though dikes were reported by prospectors and may exist in the more remote parts of the valley that were not explored. Limestones form a considerable part of the divide north of Twelvemile Creek and appear to have a general east-west trend. The direction of the structure in the schists, however, is not constant, though it, too, appears to strike east and west and to dip north.

Gravel and partly rounded morainic material extend to an elevation of 1,200 feet above the creek, or 3,600 feet above the sea, but it is not in this material that the gold values are reported to have been found. Instead, the gold is said to occur only in the cracks and crevices of the bedrock in the creek or in the very shallow present-day creek gravels. All the gold is said to be notable for its coarse size and the absence of fine flaky pieces. It is described as shaped like "pumpkin seeds," has a reddish color, and assays about \$19.20 an ounce.¹

During 1911, while the Survey party was in this region, three prospectors were met who intended to spend the winter in prospecting. They had started up Alatna River in a light-draft steamboat with supplies for two years, but about 40 miles above the mouth the boat had been stopped by low water. They therefore decided to make a rapid reconnaissance of the region and await the freeze-up before moving their supplies to the Noatak. Consequently the men, with supplies for a month, visited the headwater region and did a little surface prospecting. This work was of a decidedly superficial nature, but it is understood that the returns were not sufficient to induce the men to hold to their original plan of wintering at this place.

MIDAS CREEK REGION.

From the same prospectors noted in the preceding section, one of whom, William McCarmant, had been in the headwater region of the Noatak in 1904, it was learned that placer gold had been obtained on Midas Creek, a tributary from the north joining the Noatak near the camp of August 2. The gold was reported to have been found in small particles, all of which were rather well worn. During 1911 the Midas Creek region was again visited by these prospectors and

¹ Lloyd, L., unpublished letter.

although their work was of a superficial character certain results of significance were obtained in connection with the geologic observations made by the Survey party. It seems that much disseminated gold in fine particles was found in the creek and ancient gravels of the Noatak, both north and south of the river, but that the gravels of the tributaries of Midas Creek that are derived entirely from the hills north of the camp of August 2 are not auriferous. From the geologic study of the rocks forming these hills it is believed that they are younger than the metamorphic schists and belong to the group called in this report the Noatak sandstone. The older rocks that are more likely to be mineralized apparently form the bedrock to the south and underlie those forming the hills in which Midas Creek rises. It is therefore believed that the gold reported to have come from Midas Creek was derived either from the older rocks forming the southern part of the basin or else that it may have come from the outwash gravels which have been transported for long distances. These ancient gravels have been recognized up to an elevation of 850 feet above the mouth of Midas Creek and they are believed to have been mainly of glaciofluvial origin.

Some prospecting has also been done south of the Noatak opposite Midas Creek. Although it is reported that small colors of gold were found at many places, the abundance of large boulders in the streams makes prospecting difficult without numerous appliances not easily procurable in this remote region. The bedrock south of the Noatak at this place appears to be similar to that generally present in the better-known placer regions of the Seward Peninsula. Where the undifferentiated limestones form the hills, however, the probability of finding productive placers seems slight.

KOYUKUK BASIN.

MAIN STREAM.

According to Schrader,¹ "Placer gold has been known in the Koyukuk basin since the early nineties, if not before. It was first discovered in the bars of the river, of which the most noted seem to have been Hughes and Florence bars, both far below the present placer diggings." At the present time, however, no mining of any of these deposits is in progress, and it is probable that the production of gold from this source has been small. Maddren² estimates that about \$4,000 in gold was won from these two bars. Little is known of the origin or mode of occurrence of these placers. From prospectors' reports it appears that the gold was in very small pieces and had evidently been carried for a considerable distance. It is important

¹ Schrader, F. C., A reconnaissance in northern Alaska in 1901: Prof. Paper U. S. Geol. Survey No. 20, 1904, p. 98.

² Maddren, A. G., The Koyukuk-Chandalar gold region: Bull. U. S. Geol. Survey No. 442, 1910, p. 297.

note, however, that during 1911 placers were found on a tributary stream about 30 miles distant in the same general belt of rocks which outcrops near the river at these bars. This fact suggests that the gold may have been derived from the group of rocks that has been provisionally mapped as belonging to the Koyukuk group.

The main Koyukuk placer region lies outside of the area discussed in this report and therefore will not be described. For an account of the geology and resources of that important region, reference could be made to the other Survey publications, notably those by Schrader¹ and Maddren.²

TRIBUTARY STREAMS.

In the Hogatza basin colors of gold are reported to have been found by prospectors in some of the stream gravels. No productive areas, however, have been discovered and no prospecting is in progress.

On the headwaters of Indian River, a stream entering the Koyukuk near Florence bar, some placer mining has recently been begun. Little is known of the geology in this region. The bedrock is reported to be slate and granite and the gold occurs in shallow stream gravels. The bedrock is so disintegrated or decomposed that it can be easily shoveled into the sluice boxes and separated from the gold. Brooks³ estimates that the production from this place in 1911 was worth approximately \$14,000. Only a few claims on Felix and Snyder creeks have been developed, but prospects have been located on many of the near-by streams. The productive area is reached from Hughes in the Koyukuk by an overland trail about 25 miles long. Some 50 to 100 men were in the region during 1911, but only a few were actually engaged in mining.

The next upstream tributary on which placer has been found is the Alatna. Prospectors visited this stream in 1898 and at intervals later. A little placer gold was found in some of the gravels in that part of the valley where the southern belt of undifferentiated metamorphic schists occurs, but the indications were not sufficiently promising to induce further work and the region is now practically abandoned by prospectors.

On Mecklenberg Creek, a small tributary of Malemute River, which in turn flows into the Alatna and traverses this same general belt of undifferentiated metamorphic schists, a prospector reports having found colors of gold in the creek gravels. This locality was not visited and nothing of importance was learned of the occurrence, but no workable deposits have been developed. The gold is in small

¹Schrader, F. C., *op. cit.*

²Maddren, A. G., *The Koyukuk-Chandalar gold region*: Bull. U. S. Geol. Survey No. 442, 1910, pp. 34-415; *The Koyukuk-Chandalar region, Alaska*: Bull. U. S. Geol. Survey No. 532, 1913.

³Brooks, A. H., *The mining industry in 1911*: Bull. U. S. Geol. Survey No. 520, 1912, pp. 38-39.

particles, very few of them flaky, and is of a reddish color. No black or rusty gold was reported. In the concentrates magnetite is very abundant but garnets are only sparingly found.

Some prospecting in the Alatna basin has also been carried on in the belt of undifferentiated metamorphic schists north of the larger area of undifferentiated limestone, where the dark slates form the country rock. Two prospectors living on the Kutuk have found sufficient prospects on this stream to cause them to continue exploration, but no gravels of workable value have yet been discovered. Work at this place has been carried on only in the shallow gravels of the present stream. It is believed that the gold has been derived from quartz stringers and veins in the slate. Magnetite is abundant in the concentrates, but garnets are practically absent.

Very little prospecting has been done on John River. Schrader ¹ states that "Colors were obtained here by the writer from gravels in the mouth of a small creek near the northern edge of the Totsen series" (the southern area of undifferentiated metamorphic schists). In a subsequent report Maddren ² states:

Crevice Creek, which lies in these rocks [schists] on the east side of the river [John River], and Fool Creek and its tributaries, on the west side, are the only localities where encouraging prospects have been found up to this time [1909]. About \$1,800 worth of gold was mined on Crevice Creek in 1904 and good prospects were found on Midas Creek, a tributary of Fool Creek, in 1905, but these discoveries have not led to further development.

There seems little room to doubt that the valuable minerals in the known placers on both John and Alatna rivers have been derived from the undifferentiated metamorphic schists and their included veins. The only igneous intrusives or effusives near the placers are the greenstones.

GOLD LODES.

At the present time no lodes have been developed to a producing stage in the region, and there are very few places where even prospecting has amounted to much more than the annual assessment work stipulated by law. As usual, one of the troubles has been due to the prospectors overburdening themselves with more claims than they could handle, so that their efforts have not been concentrated on any particular place. Consequently, so far as affording information about the lodes is concerned, the prospecting has been largely valueless, and one examining the region is forced to rely mainly on natural exposures of the possible lode deposits. Indications of mineralization occur at many places, but the general inaccessibility of the region and the high valuation set on many of the prospects do not invite the investment of outside capital. Without abundant funds the developments are hampered, and many of those attempted are ill directed.

¹ Schrader, F. C., *op. cit.*, p. 101.

² Maddren, A. G., *The Koyukuk-Chandalar gold region: Bull. U. S. Geol. Survey No. 442, 1910, p. 314.*

KOBUK BASIN.

On the divide between Dahl and Riley creeks there are numerous veins in the black slates and schists. Most of these veins are small stringers, but some lenses 18 inches to 2 feet in width were noted. In the vein in particular on this divide specks of gold are reported in the quartz and a shallow prospect hole had been dug. The broken quartz from this hole had been panned, and numerous small particles of gold are said to have been obtained. On the northern slopes of this ridge, and continuing as far as the placers on Riley Creek, there is heavy quartz float all over the surface. In many pieces of the float fine gold is visible, and some pieces containing several dollars' worth of gold are reported to have been found. The auriferous quartz from this place is mostly of a dense texture and a greasy white color. Sulphides are almost entirely absent. In places the quartz is iron stained, but the discoloration is not present everywhere or in considerable amounts. The quartz in places shows indications of a comb structure, and does not seem to have been recrystallized or badly smashed. On account of these characters it is believed that the veins from which this quartz was derived belong to a series formed later than the maximum period of regional metamorphism. This interpretation is further supported by the greater continuity of these veins as compared with those in the oldest schists. It is believed that these quartz veins are intimately connected with the local placers on Riley Creek and that they are the sources from which the placer gold was derived.

An attempt to interest outside people in developing this gold quartz has so far proved unsuccessful. From the character of the exposures of quartz veins in the immediate vicinity it appears that the treatment of the vein material would require the handling and milling of a large amount of the country rock as well, and this would necessarily reduce the gold tenor. The question whether these veins can be worked is answerable only by careful and extensive sampling of the kind of material that must be mined and milled if the project is developed commercially. It is evident that picked specimens are absolutely worthless in arriving at the valuation; the samples of the vein material alone are likewise misleading.

There are many other places where veins similar to those at the head of Dahl Creek have been seen, and it is by no means improbable that they, too, carry some free gold, although in the hurried examination it escaped detection. These veins are more numerous in the areas occupied by the black slates, especially near the base of the limestones. The distribution appears to be dependent on the physical features of the slates, but the deposition of gold may have been due to chemical reactions induced by the presence of carbonaceous material throughout these rocks.

From a recent newspaper clipping it is learned that a quartz vein has been located on Hunt River near the Jade Mountains. Picked specimens from this place are reported to have yielded over \$100 a ton in gold. Nothing further, however, is known about this discovery.

ALATNA BASIN.

During the early rush into the Koyukuk some quartz veins were found in the belt of undifferentiated metamorphic schists in the central part of the Alatna basin. These were staked and held for several years, awaiting the expected boom. Practically no work was done to open up the leads, and when the place was visited in 1911 a few insignificant pits, driven on small iron-stained quartz stringers, were all that could be recognized of the early work, and the place has apparently long been deserted.

Schrader notes that in 1902-3, in the divide between the Alatna and Noatak, prospectors reported lode deposits carrying high gold and copper values. The veins were said to consist essentially of quartz with pyrite and chalcopyrite, but some specimens contained stibnite also. The location of the veins was very indefinite and they were not seen in 1911. The fact, however, that the highest assays made by the Survey of the specimens brought out by the prospectors carried less than \$2 a ton in gold, as well as the fact that no work has been done recently in the region, shows that the tenor was not sufficient to warrant development under the high costs prevailing in the upper Alatna Valley.

NOATAK BASIN.

As in other regions, reports of lost prospectors finding enormously rich deposits are common. Unfortunately, however, these "finds" can not be located when subsequently sought and their value tends to increase the less that is known about them. An instance of this sort was the reported discovery of rich gold quartz in the vicinity of Mount Kelly, a hill about 40 miles north of the camp of August 19. On attempting to learn about this gold quartz it was found that the locality was extremely indefinite, varying from the Igichuk Hills near the mouth of the river to the region beyond the Noatak drainage. It is not intended by the above remarks to cast doubt on the fact that gold-bearing quartz may have been found in the Noatak basin, but only to point out that with such indefinite location it is not possible to discuss the significance of the reported discovery. From the little that is known about the geology in the vicinity of Mount Kelly north of the Noatak, it seems probable that extensive deposits of economic value are absent, for the region is probably formed of the higher Paleozoic sediments, which as a rule are but little mineralized. There is, of course, the possibility that the pronounced deformation that is known to have affected the region may have raised the higher

beds, so that they have been removed by erosion and the older schists, which are usually more or less mineralized, may have been exposed.

Another occurrence of gold quartz has been reported from the hills south of the river, a short distance east of the canyon. A prospector, with pack horses from Squirrel River of the Kobuk basin, spent part of the fall and winter of 1910 in the hills north of Squirrel and Salmon rivers and returned with numerous specimens of quartz, some showing free gold. It was not possible to obtain a description of this trip at first hand and consequently most of the information is indefinite. That the prospector was satisfied with the indication of mineralization was shown by the report that he intended to return and carry on further exploration during the winter of 1911-12. Presumably the region has schists and metamorphic limestones as the country rock. These have usually proved auriferous.

COPPER LODES.

KOBUK BASIN.

Lodes carrying copper sulphides have been prospected at several places in the Noatak-Kobuk region, but the only systematic attempts to exploit the veins have been made in the Kobuk basin. At two places attempts have been made to prospect copper lodes, but at neither have the explorations been sufficient to determine the extent of other geologic relations of the ore. One of these prospects is located on the west side of Ruby Creek, about 5 miles from the junction of that stream with Shungnak River. The other lies west of the left fork of Ruby Creek, near the head of Cosmos Creek. A low limestone hill, locally known as Aurora Mountain, is the center around which the claims at the latter locality are grouped, and this name will therefore be used to designate that locality.

Copper-bearing leads on Ruby Creek have been known for many years and were critically examined in 1906 by experts in private employ to determine their commercial value. Conditions at that time prevented the purchase of the properties, and only a small amount of work has been done recently. Owing to the length of time that has elapsed since active work was in progress, many of the pits and open cuts have caved and filled to such an extent that they afford poor opportunity for examining the deposits and adjacent rocks. In this part of the Ruby Creek valley on the lower slopes there is a heavy covering of talus and vegetation, so that without pits and other sections many important facts are indeterminable.

Mineralization on Ruby Creek appears to be confined to a brecciated zone or zones in the limestones. Sulphides have been deposited in the open spaces thus formed and the ore-bearing solutions have penetrated the limestone along many cracks and crevices and have in

part replaced it. There is some brecciated dolomite at the mine, and this also has been replaced and intersected by sulphides. The sulphides of economic importance are mainly bornite and chalcopyrite, but galena and iron pyrite were also noted. In the surficial part of the deposit both the blue and the green copper carbonates are common. Limonite, derived from the weathering of the pyrite, in several places forms a gossan, or "iron hat," several feet thick over the sulphide-impregnated limestone. It is reported that the weathered material when panned yields colors of gold. Average pans of the gossan from an open cut above the main workings are said to give from 1 to 3 cents in gold. Assays are reported to have yielded as much as 11 per cent of copper, but no details were obtained as to the manner in which the samples were taken.

The main developments on the northernmost property consists of an adit and two open cuts. The mouth of the adit is only a few feet above the high-water level of the creek. The tunnel has been driven about 40 feet through a much slickensided and fractured limestone, in places showing mineralization. Two short drifts, totaling only about 30 feet in length, followed especially strong indications of mineralization but evidently soon passed out of rich ore. The walls stand fairly well, but caving of the surface has so blocked the mouth of the adit that 12 to 18 inches of water stands on the track. A boiler was brought in from the Kobuk by way of the low pass at the head of Wesley Creek by a team of 70 dogs. When work was started, a home-made mine car was used to tram the broken rock away from the working face, but a new automatic dumping car has since been installed. Wooden rails are, however, still in use. Natives have been employed as muckers and for the simpler mining operations are said to have given satisfaction.

On the hill at an elevation of about 150 feet above the adit an open cut about 30 feet long and 10 feet or more wide had stripped the surface and had cut into the bedrock to a depth of 5 to 7 feet. Most of this pit was covered with caved surficial material, so that little could be seen. The mineralization seemed to be essentially the same as that exposed in the adit. Although the bedrock in the open cut is limestone it differs in some respects from that exposed in the tunnel, for none of the dolomitic phase was recognized and in places it seemed to be darker and suggested correlation with a higher horizon. However, there has been so much dislocation that the structure was not determinable and in the absence of fossils the above suggestion is to be regarded as little better than a guess.

At about the same elevation above Ruby Creek as the adit already described, and 200 to 300 yards southeast of the open cut on the hill, another open cut about 30 feet long has uncovered a zone of mineralization. The mode of occurrence is essentially the same as

that at the two other places, but only the upper weathered portion has been exposed. Copper minerals are less abundant here, but there is more limonite. Sulphides were but sparingly seen; the iron occurred mainly as oxide and the copper mainly as carbonate. It is reported that samples of the ore from this cut have a higher accessory gold content than that from either of the other two places.

At a locality in Aurora Mountain, about 3 miles west of the Ruby Creek copper leads, the geologic structure is essentially synclinal; brecciated and deformed limestone forming the top of the hill lies above a series of dark slates and schists that form the lower slopes. Near the contact between the two rocks, but occurring almost invariably within the limestone, are indications of sulphide mineralization. The surface of the hill is so covered with frost-riven talus of limestone that except in artificial cuts the rocks are not exposed in place. Here and there copper carbonate float is found in considerable abundance.

Developments on Aurora Mountain consist mainly of holes dug through the overlying mantle of detritus in places where the copper float is particularly abundant. The only prospecting of this sort that has been carried to any considerable extent is on the northeastern slope of the hill about 300 feet above the contact of the limestone and schists. Exploration at this place at first consisted in sinking a shaft on the uphill side of a particularly conspicuous area of carbonate float. At the time this place was visited in 1910 the shaft was partly filled with water and its walls were so covered with ice that they could not be examined. It was reported that the shaft was about 22 feet deep and intersected a fairly promising copper lead about midway between the surface and the bottom. The bottom of the shaft is also said to have shown some good ore. Samples from the lower part of the shaft show bornite and chalcopyrite as well as carbonates.

Owing to the difficulty of mining the shaft was abandoned and a crosscut at about 250 feet lower elevation was commenced to connect with the deepened shaft. This adit was about 30 feet long, and it will be necessary to extend it over 250 feet to reach a point directly underneath the shaft. Throughout its length the adit is in barren brecciated limestone, in few places showing any mineralization. Slickensiding is evident at many places, but although the amount of throw was not determined it probably was not very great, as different rocks were not brought into juxtaposition. In spite of the brecciation and faulting the rock stands well, and it has been necessary to timber only the entrance to the adit, where it passes through the surface detritus.

Analyses by Thomas Price & Co.¹ of picked specimens of the bornite are reported to show 0.04 ounce of gold per ton, worth about 82 cents

¹ Lloyd, L., unpublished letter.

and 1.4 ounces of silver per ton, worth about 91 cents, in addition to the copper content. Assays by the same analysts of chalcopyrite from Aurora Mountain yielded 0.01 ounce of gold per ton, worth about 20 cents, and a trace of silver in addition to the copper. Neither at Ruby Creek nor at Aurora Mountain, however, does the sulphide mineralization seem to have produced auriferous placers. In Ruby Creek colors of gold have been found, but at Aurora Mountain no placer gold has been reported in the stream gravels.

Although the Ruby Creek and Aurora Mountain localities are the only ones where prospecting has been carried on, there is probably similar mineralization at many other places. In fact, mineralization near the contact of certain of the limestones and schists has been recognized all the way from Seward Peninsula to this region. So far prospecting has failed to show that any of these deposits either in Seward Peninsula or in the Kobuk region are workable.

Until the mode of origin and the general characters of ore bodies of this type are fully understood it seems unwise to do much dead work, such as running long crosscuts to intersect a possible ore body in depth. Even after a considerable body of ore has been disclosed a careful scrutiny of the costs of mining in this remote and rather inaccessible region should be made before expensive permanent mining machinery is installed. Although these facts should not discourage intelligent prospecting, they should serve as a warning that the search is likely to be expensive, as the cost of preliminary investigation will be high.

MISCELLANEOUS LOCALITIES.

Veins carrying copper and silver ores are reported by a prospector in the Noatak region. The silver ore is said to occur on the north side of the Kobuk-Noatak divide between the Reed and Mauneluk River portages. No description of the geology nor mode of occurrence was learned. The same prospector¹ reports that farther west, on the Noatak side of the pass from Kogoluktuk River, there is a considerable deposit of copper ore, and float of native copper is found in some of the streams. This place is probably in the headwaters of Ipmiluk River, a tributary of the Noatak near the camp of August 1. Assays are stated by Mr. Lloyd to have shown 9.81 per cent copper and 27.73 per cent lead; the samples, however, were not representative but selected specimens. This ore is said to carry also some gold and silver. An assay of ore from what is supposed to be a continuation of this same vein on the Kobuk side of the divide is reported to have yielded gold and silver to the value of \$1.24 a ton. No work has been done at this place, and in fact it was only discovered and a few samples taken during a hurried trip from the Kobuk to Lucky Six Creek.

¹ Lloyd, L., unpublished letter.

In the Koyukuk region, in addition to the copper sulphides already noted in the veins on the Alatna, Schrader¹ states that—

the principal specimens [of copper-bearing rocks] seen by the writer during the recent work consisted of water-worn fragments found in the John River gravels and derived apparently from the quartz veins. They contained some copper pyrites and a little uranite * * *. What is supposed to be a vein of considerable size containing iron and apparently copper pyrites was observed in a steep limestone cliff of the Skajit formation overlooking the river, where no examination or collection could be made.

COAL DEPOSITS.

KOBUK BASIN.

Coal deposits in many parts of northwestern Alaska have been described. In the Noatak-Kobuk region, however, the only place outside of Seward Peninsula where coal has been mined is near the mouth of the Kallarichuk on the Kobuk. This place was described by Stoney² as follows:

On my second trip to the Putnam [Kobuk] I discovered a vein of bituminous coal outcropping on the north side of the river about 90 miles from the mouth. I tried a bit of it in the furnace of the steam launch with very satisfactory results, though it had long been exposed to the weather. The vein was between 2 and 8 feet thick and dipped at an angle of 30° from the river.

Cantwell also tried some of this same coal in his launch, but the results were not satisfactory. Mendenhall also examined these beds and reported that—

The coals occur in low bluffs along the river, interbedded with conglomerates and fire clays. Those sufficiently well exposed for examination are of poor quality and burn slowly, yielding abundant ash and the disagreeable gases which are characteristic of impure lignites. So far as determined none of the coals outcropping here are more than 2 or 3 feet in thickness, and the majority of the seams are much thinner. Half a dozen, with a thickness of 6 or 8 inches, were examined during the reconnaissance.

During the recent development of placer mining in the adjacent Squirrel River basin some of this coal has been mined and transported for local use. In fact, a few sacks have even been carried as far as Dahl Creek, near Shungnak, for the use of the prospectors. A sample of this coal was submitted to the Bureau of Mines for analysis, with the following result:

Analysis of coal from the Kobuk basin, Alaska.

[No. 703, Laboratory No. 11097, Nov. 3, 1910. A. C. Fieldner, chemist. Air-dry loss, 2.40.]

	As received.	Air dried.	Moisture free.	Percentage referred to coal less ash and moisture.
Moisture.....	10.50	8.30	.....	.....
Volatile matter.....	28.95	20.66	32.35	35.36
Fixed carbon.....	52.94	54.24	59.15	64.64
Ash.....	7.61	7.80	8.50	.....
	100.00	100.00	100.00	100.00
Sulphur.....	0.41	0.42	0.46	0.50
Calories.....	5,852	5,996	6,538	7,145
British thermal units.....	10,534	10,792	11,534	12,861

¹ Schrader, F. C., op. cit., p. 104.

² Stoney, G. M., Naval explorations in Alaska, 1900, p. 80.

From the above analysis it is evident that the coal is a good grade of bituminous coal with a rather high efficiency. Of the Alaskan coals it most closely resembles Cretaceous coal from the vicinity of Circle and Nulato.

Some lignite was observed in the Cretaceous sandstones of the Lockwood Hills near Pah River, and coal float has also been reported on the lower part of the Ambler and on the Kogoluktuk. These localities are all in the belt of Upper Cretaceous and Eocene rocks, so that coal beds may be looked for in these rocks. So far as known, however, none of the coal beds in these rocks in this part of Alaska have proved to be of great value. The following statement¹ taken from a report of a region of similar rocks farther south, though summarizing the conclusions regarding the coal resources of that area, is equally applicable to the Noatak-Kobuk region.

From the fact that so far there is no productive mining on any of the coal-bearing rocks outcropping along the Yukon within the mapped area, it seems improbable that workable beds in the same series of rocks will be developed in the immediate future in the more remote regions, where transportation facilities and markets are wanting. Although thicker beds may be found here and there, the additional cost of transportation for each mile that the deposit lies back from the river or from some other cheap avenue of communication increases much more rapidly than the thickness of the bed could be reasonably assumed to increase.

Of course in those places where there is a local demand for coal, such as in the vicinity of active mines, the value of a near-by deposit is so great that a search for coal in the adjacent areas of Upper Cretaceous and Eocene rocks is not only warranted but necessary.

MISCELLANEOUS LOCALITIES.

Schrader² states concerning the presence of coal on John River:

Coal detritus in considerable quantity and of a character to suggest the probable occurrence of coal of economic value somewhere in the region north of this locality was seen in the John River gravels near the base of the Endicott Mountains. This coal may apparently with safety be called a good grade of bituminous. It breaks with conchoidal fracture and has a bright shiny or glossy black surface.

This coal probably comes from the Bergman group of rocks along the southern flanks of the mountains and has the same relations as the coal from the Kobuk previously described.

In the Colville basin coal has been reported at several places. The coal deposits seen by Schrader in the Upper Cretaceous to the north of the mountains lie outside the area covered by this report and their description will therefore be omitted. According to Lieut. Howard,³ coal was found on the Colville nearly due north of the camp of August 1 of the expedition of 1911. This place was described as follows:

During the forenoon we passed a hill about 500 feet in elevation, with outcrops of coal. On the sides of this hill beyond the coal were also found pieces of a substance

¹ Smith, P. S., and Eakin, H. M., Bull. U. S. Geol. Survey No. 449, p. 141.

² Schrader, F. C., *op. cit.*, p. 107.

³ Stacey, G. M., Naval explorations in Alaska, 1900, p. 69.

aled wood by the natives. It was hard, brittle, light brown in color, very light in weight, and burned readily, giving out quantities of gas. This material was scattered about in all shapes, sizes, and quantities.

In the Colville basin, according to Schrader,¹ two prospectors found coal on the Killik and used it for their camp fires. Unfortunately the position of this stream and its coal deposits is not definitely known, though Schrader indicates that the Killik lies somewhat to the north of Chandler Lake.

Farther west, in the Cape Lisburne region, coal is known to occur in the lower Carboniferous (Mississippian) rocks, so that possibly similar deposits may occur in these rocks where exposed in the Noatak basin. No coal beds nor even coal float were seen, however, and it is probable that this part of the Mississippian series does not outcrop near the river.

Near the mouth of the Noatak, not far from the camp of August 25, a prospector reported finding a recent deposit of material that he has used as fuel. Specimens from this place show a dark-brown, compact material that burns readily in the flame of a match and gives out considerable smoke and oil but leaves practically no ash. David White, who examined the material, reports that the specimen is composed entirely of large fern spores and resembles the so-called "bogheads." This deposit was not seen in place and no facts as to its extent or relations were learned. If there is enough of it the deposit should have considerable value as a local fuel.

DEPOSITS OF OTHER MINERALS.

In addition to the foregoing deposits there are others of lesser extent or value or concerning which but little is known. Thus, stibnite is said to have been found in certain of the lodes that were noted on Alatna River.

LEAD.

Galena has been found in small quantities associated with the copper sulphides at both Ruby Creek and Aurora Mountain near Shungnak. A small amount of vein quartz and some brecciated and recrystallized dolomite with galena was seen near the high hill west of Wesley Creek in the same region. A shallow prospect hole has been sunk on this stringer, but so far the indications are not at all promising.

IRON.

At places in the Kobuk region magnetite in masses as much as a hundred pounds or so in weight has been found on the surface, especially near the limestone and schist contacts. Float of this sort is particularly abundant on the slopes of the sharp conical hill locally known as Iron Mountain, east of the pass between Cosmos Creek and the left fork of Ruby Creek. Specimens from this place show a

¹ Schrader, F. C., op. cit., p. 31.

nearly pure magnetite with here and there drusy cavities lined with small octahedral crystals of this mineral. As the magnetite has not been seen in place, speculation as to its origin is hardly warranted. There are no near-by igneous rocks, so it seems improbable that these bodies are due to contact-metamorphic effects. Owing to the occurrence of limonite and hematite bodies in similar limestones in the Solomon region of Seward Peninsula, a tentative suggestion is that the magnetite of the Shungnak region may have been formed by the metamorphism of similar iron oxides which were laid down either contemporaneously with the inclosing limestones or earlier than the great period of dynamic metamorphism. The magnetite shows no signs of having been sheared, so it must have been either entirely recrystallized or deposited subsequent to the period of regional deformation.

Whatever theory of origin of these ores proves to be the true explanation probably matters little, for the deposits so far as known have but slight economic value. The high operating costs, coupled with the absence of large ore bodies, will necessarily deter capital from undertaking their development.

ASBESTOS.

Some attempts have been made to mine asbestos near Shungnak. This mineral is found in more or less close association with the greenstone intrusives. Several holes have been made in ledges of this rock on the east side of Dahl Creek above the upper placer mines, and samples of the asbestos have been submitted to manufacturers. It is reported, however, that the asbestos, although of good color, has slight tenacity, so it is not suitable for making high-grade articles and therefore commands a low price. For ordinary purposes this asbestos is well suited, but the small amount paid for this grade is not sufficient to meet the transportation charges. Furthermore, the quantity so far discovered is small, and it would therefore be expensive to mine.

JADE.

In almost all the streams of the Shungnak region north of the Kobuk boulders of a hard, green, slightly translucent rock are plentiful. These are commonly called jade, but this determination is probably incorrect. A complete examination has not been made, but most of the pieces are undoubtedly serpentine, others are green quartzite, and still others are probably nephrite. The last-named mineral is closely akin to jadeite but is an amphibole instead of a pyroxene. The two may usually be distinguished with the hand lens or by specific gravity tests, for jadeite is granular and has a specific gravity from 3.01 to 3.32, whereas nephrite is fibrous and has a specific gravity of less than 3. None of the nephrite seen

was of gem quality. The imperfections were due to cleavage, which makes the rock split into thin layers, and to inclusions of other minerals, notably magnetite, which spoil the translucency and give the stone a spotted appearance.

Stoney collected specimens of the jadelike rock and submitted them to expert examination. The report describing the various samples is as follows: ¹

Analysis of jade from Kobuk basin.

[Analyst, F. W. Clarke.]

	A	B	C	D
Carbon.....	1.78	1.38	1.76	1.73
Silica.....	58.11	55.87	56.85	57.38
Alumina.....	.24	2.07	.88	.19
Iron oxide.....	5.44	5.79	4.33	4.43
Manganese oxide.....	.38	.38	1.45	1.25
Trigones oxide.....	Trace.	Trace.	Trace.	Trace.
Loss.....	12.01	12.43	13.09	12.14
Total.....	21.97	21.62	21.56	22.71
	99.93	99.54	99.92	99.83

A. Greenish-gray, splintery, lamellar in structure.—This sample as seen in the slide and by ordinary light presents a uniformly colorless field of a homogeneous non-pleochroic mineral and is transversed by fine wavy rifts running all in the same direction. The inclosures are very minute; some are mere dustlike particles, others are distinctly recognizable as limonite. Between crossed nicols the entire field is covered with very indefinitely outlined areas, which are alternately light and dark as the stage is revolved. With a power of 230 diameters these areas are seen to be composed of wavy and uneven scales and bundles of fibers so interwoven and confused that no trustworthy measurements of extinction angles are obtainable. Many of the bundles seem to extinguish in directions approximately parallel with their length; but others show wide angles. * * *

B. Like A, but more granular.—This specimen in thin section and by ordinary light is also almost colorless, or very faintly greenish and without pleochroism. It shows only a few yellowish and opaque inclusions, which are evidently of a ferruginous nature. Between crossed nicols it exhibits the well-known nephritic structure—dense aggregate of short fibers and scales, the fibers arranged in clusters, or radiating whorllike bundles without definite boundaries, which merge into one another as the stage is revolved. In cases where these bundles are composed of fibers lying approximately parallel, angles of extinction were measured varying from 0° to 15°.

C. Paler, nearly white, closer grained.

D. Brownish, highly foliate.

Several attempts to develop the jade in the Jade Mountains west of Ambler River have been made, but so far unsuccessfully. The small and controlled market for this mineral and the inferior quality of the specimens so far found, together with the high mining costs inevitable in this rather inaccessible region, will probably prevent jade mining in these hills becoming profitable in the near future.

¹ Clarke, F. W., and Merrill, G. P., On nephrite and jadeite: Proc. U. S. Nat. Mus., vol. 11, 1888, pp. 123-130.

CONCLUSIONS CONCERNING FUTURE MINING DEVELOPMENTS.

The foregoing account of the small amount of mining or even of prospecting in the region shows that the investigation has not been adequate and that conclusions at the present time regarding the economic resources of the region have an insufficient basis of fact and are to be regarded as little more than tentative suggestions. It seems worth while, however, to state certain observations and the deductions made from them in order that the available information and theory concerning this little-known region may be at the disposal of the prospector and investor.

From what has been said of the general geography it is evident that in a region so remote and so difficult of access and having a climate so severe, the costs of transportation, supplies, and labor are necessarily high and will not materially decrease in the near future. Fish and game may be sufficient for the need of the prospector for short periods, but there is no adequate local food supply. Even wood for fuel is absent throughout a large part of the region and timber for use in mining can be procured only in a rather small area.

Although the commercial conditions will in large measure determine the future development of the Noatak-Kobuk region, the present paper deals primarily with geologic facts, and emphasis has here been placed upon these.

The basis of the first mining development in the region will probably be gold-placer deposits rather than gold lodes or veins or deposits of other minerals. It is believed, therefore, that the regions most worthy of prospecting are those in which the undifferentiated metamorphic schists form the country rock. From the geologic map (Pl. II) it may be seen that these rocks are most widely distributed in the country between the Noatak and Kobuk and are almost absent north of the Noatak or south of the Kobuk. The intricate structure of the region and the small scale of the map preclude the representation of all the details, so that the map should be regarded as indicating only the larger geologic features rather than detailed facts having but local significance.

Another geologic fact of importance that requires much study is the history of the mineralized region. Much of the area of the Noatak-Kobuk region, occupied by the undifferentiated metamorphic schists, is a highland which in the past was covered with snow and ice and had many of its valleys occupied by glaciers. Under such conditions effective sorting was reduced to a minimum and previously formed detritus was in large measure removed. This material was so mixed with glacially eroded material that there was little or no gravitative sorting. On reaching the limits of glaciation the heterogeneous débris was deposited as the ice melted and was distributed by streams. In the region where deposition was taking place, however, concen-

tion was not pronounced, for the dominant process was aggradation. As a consequence, although a large amount of material was being dumped by the ice and spread out by the streams, continued building up was taking place. It should also be noted that the ends of the glaciers were not stationary, but advanced and retreated almost continually, so whatever processes of concentration took place at the front were weakened by being dissipated over a considerable area.

It is therefore believed that in the distinctly glacial deposits extensive rich placers are but little to be expected or would have such an irregular distribution that they would be difficult to mine systematically. Here and there even in the glaciated areas, possibly some auriferous preglacial material may not have been eroded. Such auriferous deposits, however, would have a distinctly local distribution. Some of this sort may also be preserved in protected places under the mantle of outwash material. These may be of value but would be difficult to find and to mine.

With the close of the period of maximum glaciation and accompanying outwash the streams intrenched their courses in the earlier levels and now flow at many places in rather narrow trenches a hundred or more feet below the surface of these deposits. In this process concentration of these glaciofluvial deposits has been effected, but whether it has formed placers can be determined only by prospecting. From the assumed distribution and amount of gold in the outwash deposits it is probable that except under particularly favorable conditions this secondary concentration would not produce very rich placers. Places which should be examined by prospectors are those where this later sorting has affected deposits formed by a long-continued stand of the ice in one place or where reconcentration of material from early nonglacial deposits subsequently buried by outwash is actively in progress.

In spite of the difficulties that handicap immediate development and forbid large enterprises dependent on quick returns on their investment, it is believed that there is a large area of practically unknown country in the Noatak-Kobuk region that warrants investigation by observant prospectors equipped with easily transported, relatively inexpensive outfits.

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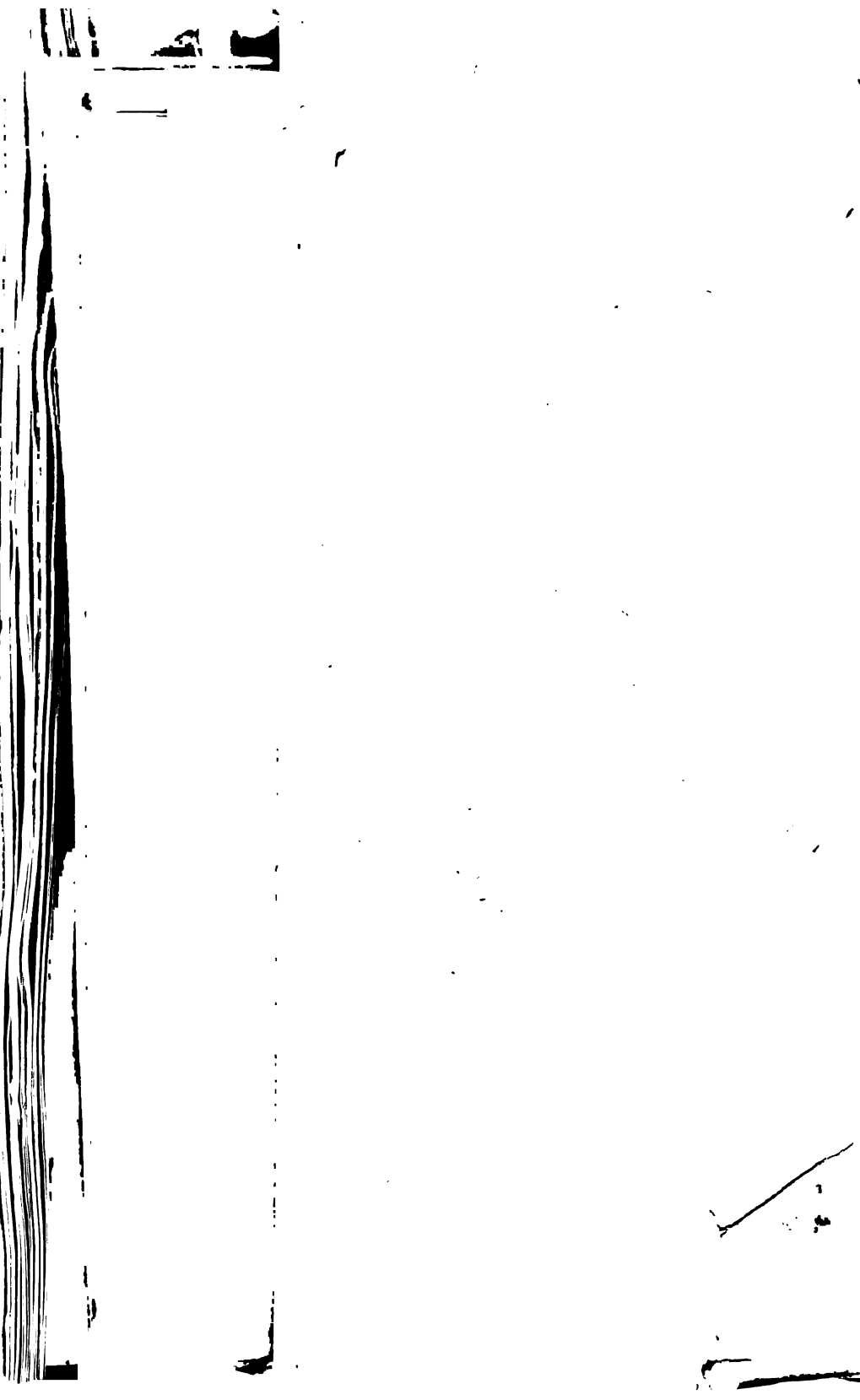
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DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

GEORGE OTIS SMITH, DIRECTOR

BULLETIN 537

THE
CLASSIFICATION OF THE
PUBLIC LANDS

BY

GEORGE OTIS SMITH AND OTHERS



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THE CLASSIFICATION OF THE PUBLIC LANDS.

By GEORGE OTIS SMITH and others.

THE PURPOSE OF LAND CLASSIFICATION.

In the latter half of the nineteenth century the spirit of the public-land laws in the United States was settlement and development. With a public domain of one and a third billion acres, acquired in the preceding half century—1803–1853—by purchase, discovery, exploration, and cession, and with another third of a billion acres in Alaska constituting a later purchase, the Nation felt that it could be lavish with its lands. The wilderness called for pioneers of every type, and large premiums were held out to capital enterprise and individual initiative. Development was desired whatever the cost in lands that were intrinsically of little value without settlement. The same century that saw the creation of this national domain—an empire in itself—also witnessed the distribution of more than one-half of its acreage. This shrinkage of the national domain has naturally been coincident with national development in all lines of industry. Western prairies have become the world's granary, and western mountains, once wholly in public ownership, are now contributing to their private and corporate owners the profits on no small proportion of the world's output of metals and of mineral fuels.

With advancing years a wise nation, like a prudent man, learns to husband its resources. Land values are now recognized, the purpose in both legislation and administration has changed, and highest development alone is sought. With the most and the best of the Nation's land already alienated, the national duty is to put to its best use what remains.

Utilization of lands for their greatest value necessitates the determination of that value, which is, briefly, land classification; and, to be adequate, land classification must be based upon first-hand acquaintance with the particular land under consideration. With a national estate including country ranging from salt-incrusted deserts to valleys knee-deep with nutritious grasses or giant forests almost impenetrable because of luxuriant undergrowth, no general statutes

that may be enacted can be made so definite as not to require the exercise of well-informed judgment in their execution. To this end examination and classification of the public lands constitute an initial step in their disposition for development and settlement. That a few decades ago settlement and development commonly outstripped classification and often far preceded even the legal disposition of the land itself is no good reason for failure to follow the more logical procedure now.

The principle of land classification is inherent in many of the public-land laws, and classification of lands has in late years been specifically recognized by Congress as a step indispensable to the administration of the national domain. This public estate is even now so extensive and valuable as to demand a business policy. Making allowance for the alienated lands included within the land units described in the various coal-land areas withdrawn by executive order for classification, and also estimating the expected reduction of these withdrawals by classification of parts of them as noncoal land, the people of the United States possess to-day 44,000,000 acres of coal lands, exclusive of the Alaskan coal fields. A large proportion of this acreage, however, is underlain by the lower-grade coals. In the almost equally important items of oil and phosphate rock the existing withdrawals indicate national ownership of over 2,000,000 acres of oil and gas lands and nearly 3,000,000 acres of lands which will furnish our agricultural regions their future supply of mineral phosphate. Nor have all the agricultural lands been alienated. Public and private irrigation projects will reclaim several millions of acres of arid land, and dry farming under the enlarged-homestead act will materially add to the area of farm lands.

To insure appropriate disposition and to secure highest use of the Nation's lands, scientific land classification by the United States Geological Survey has been made an integral part of public-land administration. Quantitative knowledge of the land and its resources is now made a preliminary, first, to disposition of lands under the various settlement and development laws; second, to reservation of lands from present acquisition pending the enactment of adequate legislation; and third, to valuation of lands under a statute which provides for their disposition at prices expressing known value.

The purpose of land classification, then, is highest utilization, and to attain this end it has been necessary to coordinate the work of scientific investigation with the administrative functions of the Department of the Interior. The large participation of the Geological Survey in the public-land administration has naturally presented problems involving changes both in office and field organization and in executive and scientific methods. For these changes

there has been little or no precedent. Scientists and public men of older countries have been outspoken in their interest in this new application of science to governmental administration, and requests have been made for more detailed information on the subject than is available in the references appearing in administrative reports of the Secretary of the Interior and his subordinates.

A new application of any branch of science necessarily affects the science itself. New use involves added requirements and in turn may contribute in by-products even more than it demands. The general effect of this direct application of the Geological Survey's investigative work to large problems of public administration is believed to have been beneficial to science itself. It has broadened the outlook of the investigator, but especially it has demanded that results be sought which are quantitatively exact as well as qualitatively true.

A full statement of the policy of land classification and a detailed description of the procedure and methods so far found necessary to carry out that policy, in the stage of development already reached, are presented in this bulletin. This information is believed to be of value both to students of government and to geologists and engineers interested in the application of scientific investigation to practical business. The historical and legal phases of the discussion may be of greatest interest to the citizen concerned in his country's highest development, while the description of field methods should be of immediate value in indicating new requirements imposed upon scientific education, for details of this business policy of the Government are already being adopted in private and corporate land examinations.

This bulletin represents contributions by many authors—members of the land-classification board and of the field branches of the Survey. The description of the development of the Survey's organization for land classification, which immediately follows this introduction, was written by W. C. Mendenhall, who as chief of the land-classification board has been directly responsible for the preparation of the bulletin. The discussion of the history and legal basis of classification was prepared by M. W. Ball, a geologist who has been identified with the work of land classification from its beginning and is now chairman of the oil section of the board.

The chapter on the classification and valuation of coal land was written by G. H. Ashley, until recently State geologist of Tennessee and now the chairman of the coal section of the land-classification board. At the time of his earlier connection with the Survey Mr. Ashley, who has made a special study of coal problems in both the eastern and the western fields of the United States, wrote the chapter on "The value of coal land" which appears in Survey Bulletin 424. In the preparation of the present paper Mr. Ashley has been most

efficiently assisted by C. E. Leshner, who is independently responsible for the short section on "The preparation of data for classification." Mr. Leshner should be credited with many of the office methods which facilitate the prompt and accurate handling of data contributed by the field men of the Survey.

Field methods are discussed by E. G. Woodruff, C. H. Wegemann, R. W. Richards, and F. R. Clark, all of whom are members of the geologic branch and have had wide experience in field work leading up to land classification. Under the topic "Oil and gas lands," J. D. Northrop, who has had experience in the California oil fields, and C. H. Wegemann, a geologist of broad experience in the Rocky Mountain fields, have collaborated in the discussion of the geologic occurrence of oil and gas, while Mr. Northrop has contributed the section on classification. In a similar way, under "Phosphate lands," A. R. Schultz and R. W. Richards, the former the chairman of the phosphate section in the land-classification board and the latter a geologist who has worked out with great thoroughness and detail the complicated structural problems of the phosphate fields in southeastern Idaho and adjacent parts of Wyoming, have collaborated in the general discussion of phosphate problems, Mr. Schultz being responsible for the section on classification. The description of potash-bearing lands and their classification is the joint contribution of A. R. Schultz and H. S. Gale, Mr. Gale being the geologist in charge of the section of nonmetalliferous deposits of the geologic branch. E. H. Finch, of the land-classification board, who has been closely identified with the cooperative work between the Survey and the General Land Office, has contributed the section on "Miscellaneous nonmetalliferous lands," and F. C. Calkins, one of the experienced economic geologists of the Survey, who has had much to do with the classification of the lands in the Northern Pacific grant, has written the discussion of metalliferous mineral lands and the problems involved in their classification. The section on "By-products of mineral-land classification" was written by G. S. Rogers, a geologist of the geologic branch, whose recent work has been done in the western coal fields.

The discussion of classification in relation to water resources has been prepared under the direction of N. C. Grover, chief engineer of the land-classification board, M. O. Leighton, Herman Stabler, E. C. La Rue, and W. B. Heroy collaborating. Messrs. Grover, Stabler, and Heroy have prepared the sections relating to classification and office procedure, while Mr. Leighton, as chief of the water-resources branch of the Survey, and Mr. La Rue, one of the experienced field engineers of that branch, have cooperated in preparing the discussion of field methods.

It is noteworthy that the authors of the sections of this publication describing the procedure employed in the work have themselves originated for the most part the methods that are so essential to successful and authoritative land classification. Mention should also be made here, however, of the important part played by A. C. Veatch, the chairman of the land-classification board at the time of its organization, by C. Willard Hayes and Waldemar Lindgren, former chief geologists of the Survey, and by M. R. Campbell, who has been in charge of the geologic work in the western coal fields continuously since 1906 and has supervised the preparation of the sections on geologic field methods in this bulletin.

DEVELOPMENT OF THE SURVEY'S ORGANIZATION FOR LAND CLASSIFICATION.

The report of the committee of the National Academy of Sciences on the surveys of the Territories, prepared in accordance with the terms of a clause in the sundry civil bill approved June 30, 1878 (20 Stat., 206, 230), contains these statements indicating the opinion of the committee as to the land-classification functions of the bureaus whose organization its members were recommending:

The best interests of the public domain require, for the purposes of intelligent administration, a thorough knowledge of its geologic structure, natural resources, and products. The domain embraces a vast mineral wealth in its soils, metals, salines, stones, clays, etc. To meet the requirements of existing laws in the disposition of the agricultural, mineral, pastoral, timber, desert, and swamp lands, a thorough investigation and classification of the acreage of the public domain is imperatively demanded. * * *

The Land Office shall also call upon the United States Geological Survey for all information as to the value and classification of lands. * * *

The publications of the Geological Survey should consist of an annual report of operations, geological and economic maps illustrating the resources and classification of the lands, reports upon general and economic geology in all its branches, with the necessarily connected paleontology.

Maj. J. W. Powell, reporting to the Secretary of the Interior on November 1, 1878, in response to the request of the acting president of the National Academy of Sciences to transmit any information available in the Department of the Interior as to surveys then in existence, after listing the classes of lands recognized under the laws, adds the following comment:

An examination of the laws * * * will show that the classes of lands mentioned above are therein recognized, and in the administration of the laws relating to these lands those belonging to each specific class must be determined; but no adequate provision is made for securing an accurate classification, and to a large extent the laws are inoperative or practically void; for example, coal lands should be sold at \$10 or \$20 per acre, but, the department having no means of determining what lands belong to this class, titles to coal lands are usually obtained under the provisions of statutes that relate to lands

of other classes—that is, by purchasing at \$1.25 per acre, or by homestead or preemption entry. An examination of the laws will exhibit this fact—that for the classification contemplated therein a thorough survey is necessary, embracing the geological and physical characteristics of the entire public domain.

After extended hearings before the House and Senate committees and the publication of many documents bearing upon the questions involved, Congress, in March, 1879, agreed upon a law which embodied the recommendations of the Academy of Sciences for the abolition of the Territorial surveys and the establishment of the United States Geological Survey but made no provision for the mensuration survey also recommended by the Academy.

Under the law approved March 3, 1879 (20 Stat., 377, 394), establishing the office of Director of the Geological Survey, it is provided—

That this officer shall have the direction of the geological survey and the classification of the public lands and examination of the geological structure, mineral resources, and products of the national domain.

Clarence King, the first Director, who entered upon his duties May 24, 1879, discusses the functions of the then newly created organization in his first annual report to the Secretary of the Interior dated November 1, 1880. In this discussion he states that—

Two special and distinct branches of duty are imposed upon the Director of the Geological Survey—(1) the classification of the public land and (2) the examination of the geological structure and mineral resources.

As regards the classification of the public lands, the text of the law leaves an uncertainty whether this classification is intended to be a scientific exposition of the kinds of lands embraced in the national domain, such as arable, irrigable, timber, desert, mineral, coal, iron, showing the practical values and adaptabilities of the various classes or kinds of soil and surface, or whether, on the other hand, it was intended to furnish a basis of classification upon which the Government should part title to portions of the public domain. * * *

Upon examination of the existing land system, I have assumed that Congress, in directing me to make a classification of the public lands, could not have intended to supersede the machinery of the Land Office and substitute a classification to be executed by another bureau of the Government without having distinctly provided for the necessary changes within the Land Office and adjustment of relations between the two bureaus. * * *

I have therefore concluded that the intention of Congress was to begin a rigid scientific classification of the lands of the national domain, not for purposes of aiding the machinery of the General Land Office by furnishing a basis of sale, but for the general information of the people of the country, and to produce a series of land maps which should show all those features upon which intelligent agriculturists, miners, engineers, and timbermen might hereafter base their operations, and which would obviously be of the highest value for all students of the political economy and resources of the United States. Studies of this sort, entirely aside from the administration of the Land Office, can be made of the highest practical value; and to this end a careful beginning has been made.

This interpretation by Director King of the duties imposed upon the new bureau by that clause in the organic act charging him with responsibility for the classification of the public lands prevailed in part until about 1906, when the pressing need of the Department of the Interior for an adequate classification of mineral lands for purposes of administration led to a revival of this suspended function of the Geological Survey, not, as Director King seemed to think necessary, by superseding the machinery of the General Land Office, but by cooperation, financial and administrative, between that bureau and the Survey and by a series of orders from the Secretary of the Interior, to whom both bureaus report. These orders so define the part that each is to bear in public-land administration as to make the Survey chiefly responsible for the physical classifications.

At first the work was concentrated largely on the classification and valuation of coal land, and this phase continues to be quantitatively the most important. In the Twenty-eighth Annual Report of the Survey, for the fiscal year ended June 30, 1907, in discussing the work on the coal lands Director Smith makes this statement:

Special investigations were conducted last year to determine the extent of the coal lands remaining in the possession of the Government and the quality and value of the coal deposits on these public lands. This work will be continued on a larger scale and under a more comprehensive plan. Special attention will be given to the classification and valuation of the coal lands and their prompt segregation from the noncoal lands. This work is to be provided for by a joint allotment from the appropriations for the geologic and topographic surveys and that for testing coals belonging to the Government, and the General Land Office is also cooperating.

The Twenty-ninth Annual Report of the Survey, for the fiscal year ended June 30, 1908, includes with some matter on the special features of the work of the Survey a discussion of land classification, which contains the following statement:

In the last few years the Geological Survey has broadened the scope of its work in the classification of the mineral lands of the public domain. At the time of the organization of the Survey the classification intended by Congress was believed to be general in character and such as could be expressed on maps issued for the general information of the people. The present interpretation of the law is that the classification should be more definite, and therefore, during the last year, the Survey has continued its special field surveys of the coal lands belonging to the Government. * * *

Increased demands have also been made on the mining geologists of the Survey for assistance in determining the mineral or nonmineral character of land for which title from the Government is sought.

This work, which has become an increasingly important feature of the Survey's activities, was definitely recognized by the organization, in December, 1908, of a land-classification board as a section of the geologic branch, and by the reorganization of the board on May 1, 1912, into a branch coordinate in rank with the other Survey branches.

The Geological Survey has been in existence as a distinct organization for about 34 years. The organizations which it succeeded and whose functions it continued to perform and gradually to enlarge upon as new duties were given it by Congress collected engineering material that was epitomized in topographic maps and geologic material that appeared either as geologic maps, as reports on geologic problems, or as data on the mineral resources of the Territories. Early in the Survey's history the necessities of its geologic work required the organization of a topographic branch for the preparation of base maps. Although these maps were intended to serve primarily as bases on which to delineate and present geologic material, they have proved to be of great value for other and wider uses. Not the least of these uses is that to which they are put in land classification. The thousands of maps issued are graphic engineering reports on the physical and cultural features of the areas they represent. They are essential to the study of drainage areas, irrigability of lands, possible power development, and rights of way, and supplemental sheets now prepared give additional data on the distribution of timber and of springs, of desert and of grass land, and of cultivated and irrigated areas.

On March 20, 1888, Congress, by joint resolution, directed the Secretary of the Interior, through the United States Geological Survey, to make a special investigation of the practicability of constructing reservoirs for the storage of water in the arid regions of the United States. This work was supported for a time by appropriations but was later discontinued by Congress after many reservoir sites had been examined and segregated and a number of reports valuable in the classification of the lands of the arid regions had been published.

After the irrigation survey was abolished the division of hydrography was organized within the Geological Survey, at first as a part of the topographic branch and later with special small appropriations, its purpose being to continue that part of the work of the irrigation survey that involved the study of the available water resources of the Western States and Territories. As the value of this work to reclamation became manifest, Congress responded by increasing the amount of the funds annually available for this purpose until in 1903 they reached the sum of \$200,000 a year.

On June 17, 1902, the reclamation act (32 Stat., 388) was passed. This act represented the culmination toward which the work of the division of hydrography had up to that time been tending. That work gave definite information as to available supplies of water and the lands on which the water could be used. The reclamation act authorized the construction of works for the application of these waters and the reclamation of the tributary lands. But the reclamation fund is not available for general studies of water supplies; it can

be used only for studies of water available for use on specific projects. The work of the division of hydrography therefore did not cease with the organization of the Reclamation Service but has been continued in the Geological Survey by the water-resources branch.

Developments within the geologic branch since its organization have likewise marked a steady evolution from its original type. The branch has grown, its appropriations and its force have increased, and its work has been more closely subdivided and specialized and has attained greater refinement in all departments; and while this evolution has been taking place it has steadily accumulated a great mass of facts bearing on the geology and mineral resources of the United States.

The material accumulated since their organization by the field branches of the Survey—the geologic branch, the topographic branch, the water-resources branch and its predecessors, the irrigation survey and the division of hydrography—constitutes a vast body of information concerning the public domain—its geology, its geography, and its water supplies and the engineering features that control the distribution of these supplies. This store of information is by no means complete, for many problems are still untouched and many areas are unexamined, but nevertheless the archives of the bureau contain a greater mass of material of the kind required for classifying the remaining lands of the public domain into types that accord with their various uses than exists anywhere else in the public records.

With the accumulation of the data indicated the Department of the Interior and its bureaus have become increasingly ready and willing to call on the Survey for assistance in that phase of public-land administration which requires as its basis a classification of the lands into the types recognized in the statutes.

The requests made by the department for information contained in the Survey's records were at first sporadic; later they became more frequent and numerous, so that it became necessary to create within the Survey itself an organization to assemble this information systematically and transmit it to the department and to other bureaus in the department in such form as would be most readily applicable to the solution of administrative problems. This organization was named the land-classification board and was first formed as a section of the geologic branch and finally made a branch of the Survey coordinate in functions and responsibility with the field branches whose evolution has been briefly outlined.

The Survey's organization for classifying the public lands consists, then, fundamentally and primarily, of three field branches—geologic, topographic, and water resources—and finally of the recently organized office branch known as the land-classification board,

with its staff of geologists and engineers, who analyze and translate into terms of public-land administration the data collected by the geologists and engineers of the field branches.

In its organization the land-classification board is in a sense a replica in miniature of the bureau of which it is a part. It consists of two divisions—a division of mineral classification and a division of hydrographic classification. The first corresponds to the geologic branch and receives, digests, and issues as land-classification data the material collected by the field geologists; the second bears a corresponding relation to the topographic and water-resources branches and similarly utilizes the engineering data gathered by the field force of those branches. Again, the division of mineral classification contains a number of sections which correspond closely with similar sections in the geologic branch. These sections, in the organization as it exists at present, are the coal section, the oil section, the phosphate section, and the metalliferous section, corresponding roughly to similar sections in the geologic branch as well as to the principal of the natural resources with which the board deals.

The work of the coal section, described elsewhere in detail, is to define the principles that shall control coal-land classification, to determine the character of the data necessary for this purpose, to receive these data as collected by the field geologists of the geologic branch, and to make and promulgate the classifications and valuations by the use of these data—this in accordance with principles already carefully defined. The coal section consists of a chairman, who is a member of the land-classification board and one of the most experienced coal geologists of the Survey, and a number of additional members, who are familiar with coal problems and are chosen usually from the geologic branch, although some have been chosen from other sections of the board. The coal section thus organized holds frequent sessions, which are attended by coal geologists who have data to present for consideration. At these sessions the problems that have arisen in the field are discussed and solved in accordance with the established rules of the board. The form and the procedure for the submission of data, including data for classification and valuation, are prescribed, and after these data are received appropriate recommendations are made to the Director for withdrawals or restorations, and valuation plats are prepared for his approval and for promulgation by the Commissioner of the General Land Office.

Each step of these various processes is carefully recorded, in order that all evidence considered and all action taken may readily be reviewed at any future time should questions arise as to the correctness of the action or should new evidence be presented. Thereafter when reports on any subdivision classified are called for by any

Government department, by other bureaus, by public officials, or by citizens, prompt response can be made in the light of all action therefore taken affecting that subdivision.

Because the laws applicable to coal lands, unlike those providing for the disposal of lands containing other minerals, authorize not merely the classification of the public domain as coal or noncoal land but the valuation and sale of the coal land at prices to be fixed in accordance with the quantity, quality, and accessibility of the coal, more complete action is possible in dealing with coal lands than with others, and the very completeness of action required involves correspondingly difficult problems.

Similar sections have been organized within the division of mineral classification for dealing with lands that may contain oil and gas, phosphate, and other nonmetalliferous minerals and for such limited and special classifications of metalliferous land as are required by law. The organization of each of these sections is similar to that of the coal section, and the action taken by them follows similar lines. Members of the land-classification board act as chairmen of the oil and gas section, the phosphate section, and the metalliferous section. Other members of the sections are selected from geologists who are engaged in field work on the particular resource which is the subject matter of the board's action.

A similar but less formal organization has been effected for the division of hydrographic classification. This division deals with those phases of land classification that depend on water supply and that involve the solution of engineering problems. The division's chief task is the classification of lands according to their irrigability and their power value, but it also reports on various complex problems which are involved in the consideration of miscellaneous rights of way. This division is administered by the chief engineer of the board. As occasion may demand, sections are organized within it for disposing of the various problems that arise. At present (1913) there are two such sections, one dealing with water powers and the other with irrigation. Each section consists of a chairman and two or more additional members, usually chosen from the engineers or hydrographic geologists of the water-resources branch. The section thus constitutes a committee which, like the sections in the division of mineral classification, may give preliminary consideration to a problem of classification (under the enlarged-homestead act, for example), or it may prepare instructions for the guidance of the field engineer or geologist and later give consideration to the data that he has obtained and prepare appropriate recommendations. The field branch with which these sections necessarily maintain closest relations is the water-resources branch, although their relation with

the topographic branch is but little less close. The graphic data on drainage areas, stream grades, reservoir sites, and general topographic features which result from the work of the topographic branch, when combined with the data on water supply assembled by the water-resources branch, furnish the basis for determining most irrigation and power problems.

In addition to the work done by these technical divisions and sections, certain miscellaneous duties are performed by means of a less well-defined administrative division of the board, whose functions are closely interwoven with those of the technical divisions and are participated in by some of the same officers. A committee, of which the secretary of the board is chairman, has charge of the filing and docketing system. The chairman of the oil section is responsible for the records in the division of mineral classification and for the details of cooperation with the Land Office and the Indian Office; the chairman of the water-power section is chiefly responsible for the records in the division of hydrographic classification.

The more important elements in the organization are set forth in the following outline:

LAND-CLASSIFICATION BOARD.

Administration.

Chief of board.

Chief engineer.

Secretary.

Division of mineral classification.

A geologist in charge.

Coal section.

Oil section.

Phosphate section.

Metalliferous section.

Division of hydrographic classification.

A chief engineer in charge.

Water-power section.

Irrigation section.

HISTORY AND LEGAL BASIS FOR LAND CLASSIFICATION.

INTRODUCTION.

Ever since the policy of selling the lands of the public domain as a source of national revenue was abandoned and the contrary policy of so disposing of them as to promote settlement and development was adopted, the administration of the land laws passed by Congress

has required a segregation of the lands into classes according with their character. It is apparent, although it has nowhere been expressly stated by Congress, that the fundamental principle guiding that body has been to dispose of each tract of the public domain for the use to which it is best adapted. Thus the laws have provided that agricultural entry should not be made upon valuable mineral lands, that lands containing deposits of coal should be sold only as coal lands, and so on for all other classes of lands. The underlying theory of devoting the public lands to their highest use and the consequent necessity for classification of uses may easily be recognized from a study of the brief outline of the more important existing land laws given on pages 20-32.

The same recognition by Congress of the necessity for land classification is shown by numerous acts calling for the classification of specific areas. Nearly every law providing for the opening of an Indian reservation has required the lands to be classified prior to their disposition. The act of February 26, 1895 (28 Stat., 683), provides and appropriates for a definite classification of lands within the limits of the Northern Pacific Railroad grant in portions of Montana and Idaho, and the sundry civil bill of June 25, 1910 (36 Stat., 739), makes further appropriation for the same purpose. The act of October 2, 1888 (25 Stat., 526), makes provision for a classification that was not necessary to the administration of the land laws then in force by appropriating \$100,000 to the Geological Survey "for the purpose of investigating the extent to which the arid region of the United States can be redeemed by irrigation and the segregation of the irrigable lands in such arid region and for the selection of sites for reservoirs and other hydraulic works necessary for the storage and utilization of water for irrigation and the prevention of floods and overflows."

A relatively recent indication of Congressional belief in land classification is afforded by the two acts of June 25, 1910, providing for the withdrawal of lands from entry, the one of public lands, the other of lands in Indian reservations. As withdrawals constitute one step in the process of classifying the public domain, the passage of bills authorizing withdrawals clearly reaffirms the established policy of land classification. One of these acts (36 Stat., 847), in terms sanctions the classification of lands, providing—

That the President may at any time, in his discretion, temporarily withdraw from settlement, location, sale, or entry any of the public lands of the United States, including the District of Alaska, and reserve the same for water-power sites, irrigation, classification of lands, or other public purposes to be specified in the orders of withdrawals, and such withdrawals or reservations shall remain in force until revoked by him or by an act of Congress.

The other (36 Stat., 855) provides—

That the Secretary of the Interior be, and he is hereby, authorized, in his discretion, to reserve from location, entry, sale, allotment, or other appropriation any lands within any Indian reservation, valuable for power or reservoir sites, or which may be necessary for use in connection with any irrigation project heretofore or hereafter to be authorized by Congress.

Thus the plain intention of Congress that the public lands shall be classified and that they shall be disposed of in accordance with their classification is shown by definite provisions for the classification of certain areas, by the authorization of land withdrawals, and by the creation of an organization—the Geological Survey—among whose prescribed duties the classification of the public lands is specifically stated. But were there none of these evidences the fact that Congress has consistently recognized the necessity for the classification of public lands would be established beyond question by a study of the land laws, which, as the following brief outline will show, could not be administered without some sort of segregation into classes. This outline does not purport to set forth in detail all the laws under which disposition is made of the public lands; it only sketches the principal features of the more important laws.

LAND LAWS.

GENERAL DIVISIONS.

The land laws of the United States may be divided into two distinct classes—public-land laws and land grants. The first are general laws providing for the disposition of lands to any duly qualified person who may wish to avail himself of the prescribed conditions; the second are special laws granting certain areas to specified individuals, corporations, or State governments. The laws of each of these two classes may in turn be subdivided, the public-land laws falling loosely under the headings of agricultural, mineral, and coal land laws and laws relating to public and quasi-public uses, whereas land grants may be divided into grants made to States and grants made to railroads.

PUBLIC-LAND LAWS.

AGRICULTURAL-LAND LAWS.

Purpose.—In general, the purpose of the laws relating to agricultural land is to promote the settlement of the public domain. The principal acts are those providing for homesteads, forest homesteads, enlarged homesteads, desert-land entries, entries under the reclamation act, the sale of isolated tracts, and timber and stone entries. Every tract of land to which these laws are applied must be nonmineral in character.

Homesteads.—The homestead act was passed by Congress in 1862 and was approved by President Lincoln on May 20 of that year (Rev. Stat., 2289–2303). It marked the final abandonment of the policy of disposing of the national domain as a means of providing public revenue. Until 1912 the homesteader was required to establish a residence on his land and to reside thereupon for a period of five years. No definite amount of cultivation was required, but the building of houses and barns and the cultivation of a part or all of the area were regarded as evidence of the good faith of the entryman in entering the land for the purpose of building a home for himself, this being the fundamental object of the homestead act. On June 6, 1912 (37 Stat., 123), the law was amended by reducing the five years' residence theretofore required to a residence of three years. The requirement as to residence is modified by what is known as the "commutation clause" (Rev. Stat., 2301, as amended by the act of March 3, 1891, 26 Stat., 1098), which provides that after 14 months' residence and cultivation title may be obtained by paying a fixed price per acre, this price being either \$2.50 or \$1.25, the first if the land is within, the second if it is without the limits of a railroad grant. Homesteads reserving coal or oil and gas to the Government under the acts of June 22, 1910 (36 Stat., 583), and August 24, 1912 (37 Stat., 496), described later (p. 45), may not be commuted. The amendment of June 6, 1912, also provides that the entryman must cultivate "not less than one-sixteenth of the area of his entry beginning with the second year of the entry and not less than one-eighth beginning with the third year of the entry and until final proof." The homestead act contains the clause "nor shall any mineral lands be liable to entry and settlement." The area of the homestead is restricted to 160 acres.

Forest homesteads.—Lands in national forests are not in general open to agricultural entry, but under the act of June 11, 1906 (34 Stat., 233), forest-reserve lands which are chiefly valuable for agriculture, which are not needed for public purposes, and which, in the opinion of the Secretary of Agriculture, may be occupied without injury to the forest, may be entered under the homestead laws. Application for a particular tract desired, which must not exceed 160 acres in area nor 1 mile in length, must be made to the Secretary of Agriculture. The land is then examined by a field agent of the Forest Service, and if his report is favorable the land is listed to the Department of the Interior, where homestead entry is allowed. The entry thereafter proceeds as would any other entry under the homestead law, but no commutation is permitted. The law differs from all other agricultural-land laws in that the land must be chiefly valuable for agriculture and that the entry may be described by metes and bounds instead of by legal subdivisions of the public-land survey.

Enlarged homesteads.—An act known as the enlarged-homestead act, approved February 19, 1909 (35 Stat., 639), provides that in the States of Colorado, Montana, Nevada, Oregon, Utah, Washington, Wyoming, Arizona, and New Mexico a homestead entry may comprise 320 acres of nonmineral lands which have been designated by the Secretary of the Interior as not susceptible of successful irrigation at a reasonable cost from any known source of water supply. On June 17, 1910 (36 Stat., 531), a similar act was approved applying to Idaho, and on June 13, 1912 (37 Stat., 132), one applying to California and North Dakota. The requirements as to residence and cultivation on an "enlarged homestead" are, under the act of June 6, 1912 (37 Stat., 123), the same as those for other homesteads, but enlarged-homestead entries may not be commuted by cash payment. The enlarged-homestead acts further provide that tracts in the States of Utah and Idaho which have not upon them "such a sufficient supply of water suitable for domestic purposes as would make continuous residence upon the lands possible" may be subject to entry without the necessity of residence, but one-eighth of the area of the entry must be cultivated from the beginning of the second year and not less than one-fourth from the beginning of the third year until final proof has been submitted.

Desert land.—Under the desert-land acts entry may be made on lands which, by reason of lack of rainfall, will not produce native hay or other agricultural crops or trees without irrigation. Such lands may be entered by irrigating and producing crops on not less than one-eighth of the area. No residence is required. Any person duly qualified may enter an area not exceeding 320 acres of such lands. It should be noted, however, that this 320-acre area is limited by the fact that one person is not permitted to acquire more than 320 acres of land under the public-land laws, mineral entries not being taken into account. The entryman is given three years in which to reclaim his land, which must be nonmineral in character.

Reclamation act.—Under the act of June 17, 1902 (32 Stat., 388), the Government is building great irrigation projects for the reclamation of arid and semiarid lands in the West. Lands thus reclaimed, which must be nonmineral in character, may be entered by any person qualified to make a homestead entry. The enterable area is not more than 160 acres but is different in the different projects and in different parts of the same project. No charge is made for the land, but the entryman must pay his proportional part of the cost of the project in ten yearly installments. Three years' residence on the land is required, as under other homestead laws, and at least one-half the area of the entry must be cultivated before title can be obtained.

Isolated tracts.—Small tracts of public land surrounded by lands which have already been entered may be purchased as isolated tracts

under section 2455 of the Revised Statutes as amended by the act of June 27, 1906 (34 Stat., 517). Under the act of March 28, 1912 (37 Stat., 77), mountainous tracts which are not isolated by entered land but which are unfit for cultivation may be purchased by the owner of adjoining land in the same manner as isolated tracts. A person desiring to purchase land in this manner files with the local land officers an application to purchase, whereupon, if the lands are nonmineral and are in fact isolated or mountainous, a public sale is advertised, at which the lands are sold to the highest bidder. No residence or cultivation is necessary, but the land must be nonmineral.

Timber and stone lands.—The foregoing five classes of laws constitute the principal types under which agricultural entry may be made. There remains a sixth class of considerable importance, which, while applying only to lands more valuable for other purposes than for agriculture, is nevertheless more nearly allied to the agricultural laws than to the laws relating to minerals, coal, or quasi-public uses. Under the act of June 3, 1878 (20 Stat., 89), and acts amendatory thereof nonmineral lands which are valuable chiefly for the timber and stone thereon and which are unfit for cultivation may be appraised and sold at not less than \$2.50 per acre. Application to purchase is made in a manner similar to that required by the laws relating to isolated tracts, but there is no public sale. There is instead an appraisement of the value of the land by an appraiser designated by the Government, and the lands are purchased at the price so fixed.

MINERAL-LAND LAWS.

General provisions.—The mineral-land laws were in the main formulated in the 10 years between 1865 and 1875. They are based largely on local mining customs which had attained the force of law in the mining camps on the public domain. Their constant purpose has been to promote mineral development. The act of May 10, 1872 (Rev. Stat., 2319), provides that "all valuable mineral deposits in lands belonging to the United States, both surveyed and unsurveyed, are hereby declared to be free and open to exploration and purchase, * * * by citizens of the United States and those who have declared their intention to become such." No important amendment of the mining laws has been made since the date of this act. At that time the known deposits of importance on the public domain comprised only metalliferous minerals, and the laws were framed with such deposits in mind, provision being made for two classes of claims—lode and placer. From time to time since the adoption of the mining laws one and another nonmetalliferous mineral has become important, and its entry under the placer law has been authorized by Congress, which has thus specially provided for the entry of lands that are chiefly valuable for petroleum, salines, and building stone.

The general procedure under the mineral-land laws is the same for all classes of deposits. The person who desires to obtain mineral lands must first make a discovery of valuable mineral within the limits of the claim that he wishes to locate. This discovery, as interpreted by the Department of the Interior and the courts, must be such a showing of mineral as would warrant a man of ordinary prudence in expending his time and labor upon the claim in the reasonable hope and expectation of developing a paying mine thereon, or, as expressed in one of the latest decisions (40 L. D., 271) interpreting the lode law, "there must be actually physically exposed" within the limits of the claim "a vein or lode of mineral-bearing rock in place, possessing in and of itself a present or prospective value for mining purposes." The method of location, the posting of location notices, and other similar matters are determined by the local customs or miners' rules of the district in which the claim is situated. In order to hold a claim against possible adverse claimants—in other words, to prevent its being jumped—at least \$100 worth of work, called "assessment work," must be performed on it each year. After \$500 worth of assessment work has been done and certain requirements as to recording and surveys have been met, the applicant, on payment of a fixed price per acre, is entitled to patent.

Lodes.—Claims for veins of quartz or other rock in place are known as lode claims (Rev. Stat., 2320). Their size is governed by the rules of the mining district in which they are situated but must not exceed 600 feet in width and 1,500 feet in length. Claims need not conform to the public-land system of surveys and may be in almost any shape, provided only that the end lines of each claim shall be parallel. When patent is sought, a purchase price of \$5 an acre must be paid.

All veins that come to the surface within a given claim are the property of the owner of that claim through their entire depth (Rev. Stat., 2322) but only for such portion of their extent as lies between the end lines of the claim. Thus the owner of the outcrop or apex of a lode may follow it downward indefinitely so long as he stays within his end lines and may mine it without regard to the ownership of the land under which it passes. This provision, which is known as the "law of the apex," has unquestionably been more provocative of litigation than any other provision of American land law.

The lode law provides also for the discovery in driving tunnels of veins not outcropping on the surface and not previously known to exist. It grants to the discoverers the right to 1,500 feet of extent of each vein so discovered within 3,000 feet of the face of the tunnel, with the same apex right as if the discovery were made at the surface. Failure for six months to prosecute work on a tunnel acts

as an abandonment of the right to veins which may subsequently be encountered.

The number of claims which may be entered by one person under the lode law is unlimited, provided he does the necessary assessment work and otherwise complies with the law for each claim. Moreover, the owner of a group of claims may concentrate his assessment work on one claim of the group if such work tends to the development of every claim in the group.

Placers.—The placer law, which was approved July 9, 1870 (16 Stat., 217), was intended to apply to gold and silver distributed through deposits of sand and gravel. As at that date there were no known important mineral deposits except veins and placers, the law provides (Rev. Stat., 2329) that "placer" claims shall include "all forms of deposit, excepting veins of quartz or other rock in place." These placer claims are subject to entry and patent in a manner similar to lode claims, but where the lands have been surveyed the claim must conform to the legal subdivisions of the survey. The purchase price is \$2.50 an acre. The maximum area that may be included in one claim by an individual is 20 acres, although, as in lode claims, there is no limit to the number of claims that may be entered. An association may enter in one claim an area equal to 20 acres for each member but not more than 160 acres. Only one discovery of mineral is required to support a placer location, whether it be of 20 acres by an individual or of 160 acres by an association. The applicant for a placer claim must make affidavit that there is not within the limits of the claim any valuable vein or lode and also that title is not sought in order to control watercourses or to obtain valuable timber. The assessment work on each claim, whether of 20 or 160 acres, must amount to \$100 a year and to \$500 before patent may be issued. On placer as on lode claims annual assessment work to the amount of \$100 for each claim in a group may be done on any one of the claims in the group, provided it tends to the exploration or development of all.

Building stone.—By the act of August 4, 1892 (27 Stat., 348), the placer law was extended to apply to lands chiefly valuable for building stone. The requirements as to discovery, assessment work, area, and price are the same as for other placers. It is to be noted that in this act the factor of relative value was for the first time specifically introduced into mineral-land law. The earlier laws provide for mineral entry on lands which are valuable for their mineral deposits. It has been argued that only lands whose mineral value is greater than their agricultural value are properly enterable as mineral land, and the decisions of the department and the courts can not be said to have settled the matter conclusively. In the building-stone and

subsequent extensions of the placer law, however, it is specifically stated that the lands must be chiefly valuable for the mineral upon whose discovery the claim is based.

This extension of the placer law to cover building stone neither repealed nor conflicts with the timber and stone act of June 3, 1878 (20 Stat., 89), already discussed. Thus lands chiefly valuable for building stone may be purchased at an appraised value not less than \$2.50 per acre or may be entered under the placer law and patented after the completion of the required amount of assessment work, on payment of \$2.50 per acre.

Oil.—About a quarter of a century after the passage of the placer law valuable deposits of petroleum were discovered on public lands. The discoverers, finding themselves without an appropriate law under which to apply for a patent, made application under the placer law—not because it was fitted to the needs of the situation but because of its general provision that all forms of deposit excepting veins of quartz or other rock in place should be entered thereunder. The Department of the Interior, recognizing the undesirability of applying the placer law to oil and gas, refused to allow the applications. On an appeal to Congress for relief, the act of February 11, 1897 (29 Stat., 526), was passed, providing that lands chiefly valuable for petroleum and other mineral oils should be enterable under the placer law. On February 12, 1903 (32 Stat., 825), specific authority was granted for doing assessment work on any one of a group of oil claims lying contiguous and owned by the same person or corporation, not exceeding five claims in all, provided that such assessment work tends to develop or determine the oil-bearing character of all the claims. The requirement of discovery of valuable minerals as a prerequisite to location—a requirement reasonable enough when applied to veins outcropping at the surface or to gold placers—is applied as rigidly to deposits of oil and gas, which, as a rule, can be discovered only after long and expensive exploration, as to other minerals. Lands included in petroleum placers, like those entered for building stone, must be chiefly valuable for the purpose for which they are claimed.

Salines.—The act of January 31, 1901 (31 Stat., 745), extends the placer law to cover lands that contain salt springs or deposits of salt in any form and that are chiefly valuable therefor. This has been interpreted as including only sodium chloride, no specific provision having been made for other soluble salts. The requirements as to area, assessment work, and price are those contained in the original placer law, except that the same person may not locate or enter more than one claim. The consideration of relative worth is again introduced.

COAL-LAND LAWS.

The law under which disposition is made of coal differs so radically from the laws regarding other minerals that it is not ordinarily classed with the mineral-land laws. It was approved March 3, 1873 (17 Stat., 607), and was incorporated into the Revised Statutes as sections 2347 to 2352. Any qualified person may purchase an area of coal land not exceeding 160 acres on payment of not less than \$10 an acre if the land is more than 15 miles from a railroad and not less than \$20 an acre if the land is within 15 miles of a railroad. An association of persons severally qualified may purchase 320 acres. An association of four or more persons who have opened and improved a coal mine upon the public lands and have expended not less than \$5,000 in working and improving it may enter an area not exceeding 640 acres. No person may make more than one coal entry, either individually or as a member of an association, and no association any member of which has previously exhausted his coal right may purchase coal land. A person or association opening a mine on the public lands is entitled to a preference right of entry for the lands on which the mine is situated, provided that a "coal declaratory statement" is filed within 60 days from the initial date of actual possession and the commencement of improvements upon the land. This preference right is good for one year only. The operation of the law is restricted to surveyed lands, which must not be valuable for their content of gold, silver, or copper.

For over 30 years after the passage of this law all coal lands were sold at the minimum prices of \$10 and \$20 an acre prescribed by the statute. Since 1907 the selling prices have been fixed by the Geological Survey and have ranged from the minimum prices up to \$600 an acre.

LAWS RELATING TO PUBLIC AND QUASI-PUBLIC USES.

The laws governing public and quasi-public uses of land differ from the other laws under discussion in that they provide for the use of rights of way for various specified purposes and do not contemplate the transfer to the beneficiaries thereunder of fee title to the land affected.

Railroads.—By the act of March 3, 1875 (18 Stat., 482), Congress granted to railroad companies right of way to the extent of 100 feet on each side of the center line of a proposed railroad through the public lands, under prescribed conditions. Upon the approval by the Secretary of the Interior of the location map filed by any railroad company, the road as located is noted on the plats in the General and local land offices, and thereafter all public land over which such right of way passes is disposed of subject to such right of way. By act of March 2, 1899 (30 Stat., 990), Congress provided for similar

rights of way across Indian reservations, and by the act of March 3, 1899 (30 Stat., 1233), the Secretary of the Interior was authorized to approve rights of way for wagon road, railroad, or other highway across any forest reservation or reservoir site when in his judgment the public interest would not be injuriously affected thereby.

Irrigation.—By act of March 3, 1891 (26 Stat., 1095), Congress granted to canal and ditch companies formed for the purpose of irrigation the right of way for canals, ditches, and reservoirs to the extent of the ground occupied and 50 feet on each side of the marginal limits thereof, across public lands and reservations, provided that no such right of way shall be so located as to interfere with the proper occupation by the Government of any such reservation and that all maps of location shall be subject to the approval of the department of the Government having jurisdiction over such reservation. Upon the approval by the Secretary of the Interior of the location map the right of way is noted on the plats in the General and local land offices and thereafter all public land over which the right of way passes is disposed of subject to such right of way. By act of May 11, 1898 (30 Stat., 404), the use which may be made of the canals, ditches, and reservoirs for which right of way is secured under the act of 1891 was extended to include purposes of a public nature, water transportation, domestic purposes, and the development of power, as subsidiary to the main purpose of irrigation. The act of February 15, 1901 (31 Stat., 790), which provides for the issuance of revocable permits for the development of power, covers also canals, ditches, pipes and pipe lines, flumes, tunnels, or other water conduits and water plants, dams, and reservoirs used to promote irrigation.

Power.—Power development on the public lands and reservations can at this time (February, 1913) be accomplished only under the act of February 15, 1901 (31 Stat., 790), except that power development subsidiary to the main purpose of irrigation may be made under the irrigation acts and that power development on national forests for mining, milling, and municipal purposes may be made under the act of February 1, 1905 (33 Stat., 628). The act of February 15, 1901, authorizes the Secretary of the Interior to issue revocable permits, under general regulations to be fixed by him, for rights of way for electrical plants, poles, and lines for the generation and distribution of electrical power to the extent of the ground occupied by the works and not to exceed 50 feet on each side of the marginal limits thereof. The law provides that permits issued under this act shall not be held to confer any right, easement, or interest in, to, or over any public land, reservation, or park. The act of March 4, 1911 (36 Stat., 1253), authorizes the head of the department having jurisdiction over the lands to grant rights of way for a period not

exceeding 50 years upon the public lands, national forests, and reservations for poles and lines for the transmission and distribution of electrical power, to the extent of 20 feet on each side of the center line.

Mining and milling.—The act of February 1, 1905 (33 Stat., 628), grants rights of way within or across national forests for dams, reservoirs, water plants, ditches, flumes, pipes, tunnels, and canals for mining purposes and for the purposes of the milling and reduction of ores. Outside of the national forests the use of similar rights of way for these purposes may be made only under revocable permit under the act of February 15, 1901.

Municipal uses.—Rights of way for municipal use for procuring water supply or for developing power may be obtained within a national forest under the act of February 1, 1905, and outside of the forests under the act of February 15, 1901.

LAND GRANTS.

GRANTS TO STATES.

In aid of schools and State institutions.—The Congress of the Confederation, about 1785, declared that to each State created out of the public domain there should be given a certain portion of each township in the State, the proceeds derived therefrom to be used for public education. Accordingly, when the first State, Ohio, was admitted into the Union from the public domain, April 30, 1802 (2 Stat., 173), sec. 16 of each township was granted for the establishment of a school fund. As other States have been admitted this practice has been deviated from only in adding to the acreage granted. Sec. 16 has been a school section in every public-land State; to this sec. 36 has been added in many States, and in some States secs. 2, 32, and 36. The title of the State to these sections attaches immediately upon survey, unless the lands are at that date known to be mineral in character or are included in a valid settlement or other claim under the public-land laws or are within a forest, military, Indian, or other reservation. In any of these contingencies the State does not obtain title, but may select an equal area of nonmineral lands elsewhere. These are known as indemnity lands. As a rule they are not at once selected by the States but are selected only as the demand for specific lands arises.

In addition to granting school lands in place and their associated indemnity lands, Congress has made to certain States "quantity grants"—that is, grants of specified quantities of nonmineral lands wherever the State may choose to select them—in aid of State institutions, such, for example, as insane asylums. Selection rights under these grants, like those under the indemnity lists, are as a rule exer-

cised by a State only when individuals or corporations purchase the right to select certain desired lands.

In aid of internal improvements.—In the early days of the country's history the right of Congress to grant public lands in aid of internal improvements was bitterly contested. The first legislation of this character was contained in the enabling act of the State of Ohio, already cited, and provided that one-twentieth of the proceeds of the sale of public lands within the State should be given to the State to be used in establishing public roads. The first grant of specific lands in aid of internal improvements was not made until February 28, 1823 (3 Stat., 727). This grant also was made to the State of Ohio to aid in the construction of a wagon road. Since that time there have been ten other wagon-road grants, eight canal grants, three river-improvement grants, and twenty railroad grants. The railroad grants to States alone approximate 40,000,000 acres. No grant to a State in aid of internal improvements has been made since the grant to Oregon for the Coos Bay wagon road on March 3, 1869 (15 Stat., 340). Although these grants were in terms made to the States, most or all of them were in fact made through the States to corporations that carried out the improvements contemplated.

Carey Act.—The act of August 18, 1894 (28 Stat., 372, 422), commonly known as the Carey Act, and amendments thereto, the purpose of which is to aid the public-land States in the reclamation of the desert lands therein and in the settlement, cultivation, and sale of such lands in small tracts to actual settlers, authorize—

(a) The temporary withdrawal of public lands from settlement or entry pending investigation and survey preliminary to the filing of an application for segregation, such withdrawn lands to be restored to settlement and entry at the end of one year from the date of withdrawal in case application for segregation is not theretofore made.

(b) The segregation of public lands by the Secretary of the Interior, contracts between the United States and any beneficiary State, and the reclamation of such lands by beneficiary States within 10 years from the approval of the State's application (subject to an extension of 5 years).

(c) The patenting to any beneficiary State of any tract of reclaimed land when satisfactory proof is made that an ample supply of water to reclaim it is actually furnished.

Other important provisions of the Carey Act are in brief as follows:

Prior to segregation of lands or execution of contract between the United States and any State, such State shall file a proper application and present satisfactory plans for the reclamation of the lands. Lands that are not desert, lands that are occupied by bona fide set-

tlers or under the mining laws, unsurveyed lands occupied with a view to entry under the desert-land laws, and lands containing valuable deposits of minerals other than coal are not subject to segregation. Coal lands (in Utah oil and gas lands also) may be segregated, but when patent is issued it must contain a reservation of these minerals to the United States.

The usual procedure under the Carey Act is about as follows:

A corporation or individual applies to the State for the withdrawal of certain public lands proposed for irrigation. The State thereupon submits to the Interior Department an application for their withdrawal. On the approval of this application the State is allowed one year in which to investigate the project and prepare satisfactory plans for reclamation. The proposing company conducts the investigations and if a project that is considered feasible is developed makes application to the State for the segregation of the irrigable lands and offers to contract with the State for their reclamation. The State thereupon applies to the Interior Department for the segregation of the lands under the terms of the Carey Act and its amendments. If the plan of irrigation is found to be feasible, the irrigation company responsible, and the available water supply adequate, the lands are segregated and the contract for their reclamation is entered into between the United States and the State. When the irrigation works are completed to the satisfaction of the Government, patent is issued to the State or to its assigns. The State receives payment for the lands from the settler, and the irrigation company, either directly or through the State, receives payment from each settler for his proportionate share of the irrigation works and water rights involved.

RAILROAD GRANTS.

As already indicated, most grants of public lands in aid of internal improvements have been made through the States. Eight grants, however, have been made by Congress directly to corporations, to encourage the building of railroads. Four of these grants, aggregating approximately 109,000,000 acres, were made to Federal corporations created by Congress for the purpose of building the roads subsidized, and four were made to State corporations. Of the four grants to State corporations, two were declared forfeited by Congress in 1874, the two remaining aggregating approximately 6,000,000 acres. The first of the grants made directly to corporations was the Pacific railroads bill of July 1, 1862 (12 Stat., 489), which provided for the building of the Union Pacific-Central Pacific line from Missouri River to the Pacific coast. This act granted to the railroad every alternate section for 20 miles on either side of the right of way. The Northern Pacific grant of July 2, 1864 (13 Stat., 365), conveyed every alternate

section for 40 miles on either side of the right of way. The grant to the Atlantic & Pacific Railroad Co. (now the Atchison, Topeka & Santa Fe) was made by the act of July 27, 1866 (14 Stat., 292). These three grants contained no restrictions as to the use to be made of the lands, but certain of the later grants required the lands to be sold only to actual settlers at prices not to exceed \$2.50 an acre. The last of the railroad grants was made to the Texas Pacific Railroad Co. on March 3, 1871 (16 Stat., 573). Since that time Congress has consistently refused to grant lands, either to States or to corporations, in aid of internal improvements.

All the railroad grants were restricted to lands containing no minerals except coal and iron. These two were given to the railroads because of their use in the construction and operation of the roads. In certain cases the railroads were permitted to select other lands in lieu of those which, normally constituting a part of the grant, proved to be valuable for minerals other than coal and iron or to be included within Indian or military reservations or national forests or to have been covered by valid settlement. The right to make these lieu selections is usually sold by the railroads in the form of "scrip," which may be filed on any vacant unreserved nonmineral land.

NECESSITY FOR LAND CLASSIFICATION.

A study of the land laws shows the absolute necessity of some form of segregation of the lands into classes as a prerequisite to their disposition. Agricultural entry may not be made on lands containing valuable minerals, nor coal entry on lands containing gold, silver, or copper; lands included in desert entries or selected under the Carey Act must be desert lands; enlarged-homestead lands must not be susceptible of successful irrigation; placer claims must not be taken for their timber value or their control of watercourses; and lands included in building-stone, petroleum, or salt placers must be more valuable for those minerals than for any other purpose. So through the whole scheme of American land laws runs the necessity for determining the use for which each tract is best fitted.

No specific financial provision has ever been made for a systematic classification of the entire public domain into classes representing the highest use for each area. Such a scheme, with proper provision for revisions whenever necessitated by changing conditions or increased knowledge, would be of immense value in the administration of the public domain, and if it had been initiated when the major portion of the public-land laws were in process of formation it would have saved to the public natural resources of immense value. It can hardly be questioned that the National Academy of Sciences had in mind such a systematic classification of the entire public domain

when it recommended the creation of the Geological Survey, but the new organization when created was not supplied with the funds to carry forward a work of such magnitude. The classification of coal lands and the segregation of lands valuable for oil, gas, phosphate, potash, water power, and reservoir sites constitute a tardy and very meager attempt to meet the need for a universal classification.

In default of a classification of the entire national domain the land department early adopted the expedient of requiring a classification of each tract of land at the time of its disposition. These classifications in general originated from four sources—first, from the applicant for the land; second, from deputy surveyors; third, from members of the Land Office field service; and fourth, from the Geological Survey. It is the present purpose to discuss the first three types of classification somewhat briefly and the last in considerable detail, and to show the weight given to each type and the results.

AGENCIES AND METHODS OF CLASSIFICATION.

CLASSIFICATION BY AFFIDAVIT OF APPLICANT.

Nearly every applicant for public land is required to submit an affidavit that the land desired is of a character properly subject to the proposed entry or selection. Every applicant under the agricultural laws must set forth by his own oath and that of two witnesses that the lands are nonmineral in character. The State in selecting indemnity or "quantity grant" lands must make affidavit to their nonmineral character. Mineral applicants must state under oath the discovery of valuable minerals, and similar affidavits are required of most if not all applicants.

Less and less weight has been given in recent years to classifications so made. It has been found that the affidavits of interested parties, whether furnished by individuals or submitted by sovereign States, do not furnish a reliable basis for the disposition of public lands. Furthermore, the determination of the mineral or nonmineral character of a particular tract may be too difficult and too complex a problem for solution by other than a special trained expert. At present all agricultural entries except homestead and desert-land entries on unwithdrawn lands are classified as to mineral character and power-site or reservoir value either by examination on the ground by the Land Office field service or by the Geological Survey from information contained in its records or procured by special examination. Thus, although the affidavit of the applicant has not been abandoned, it is of little importance. Similarly mineral claims in national forests are subjected to examination before the applicant's affidavit of discovery is accepted, and classification by the entryman or selector is in general being replaced by classifications made by the Government.

CLASSIFICATION BY DEPUTY SURVEYORS.

The regulations for the survey of public lands require the deputy surveyor to note and report all occurrences of mineral. These requirements have varied from time to time. In certain periods the deputy surveyor has reported a somewhat detailed classification of the lands surveyed into first-class agricultural, second-class agricultural, grazing, mineral, timber, etc. At one time all lands reported by deputy surveyors to be mineral in character were withheld from agricultural entry, but the inaccuracy of the segregations and the magnitude of the areas involved led to a general order throwing all such lands open to all forms of entry. The only present result of a report by a deputy surveyor that land is mineral is to subject agricultural entries to a more careful scrutiny than would otherwise be made.

CLASSIFICATION BY LAND OFFICE FIELD SERVICE.

The General Land Office has a well-organized field service engaged in the examination of entries and selections of public lands. All agricultural entries or selections, including State selections and railroad lieu selections but excepting homestead and desert-land entries on unwithdrawn lands, are examined by this field service as to their mineral character and power-site or reservoir values, unless the Geological Survey is able from its records to make a classification of the lands. Formerly the reports of the members of the field service were accepted as final without review outside of the Land Office and the Secretary's office, and, as a result, some classifications by the Geological Survey were overruled by the Land Office. The resulting confusion led to the adoption of cooperative agreements between the two organizations, whereby the information gathered by each is made fully available to the other. The first of these agreements was entered into July 10, 1910. It has been replaced by a more comprehensive and more systematic agreement adopted March 5, 1912. Under this agreement all entries, selections, or applications except metaliferous mineral entries, coal applications, and homestead and desert entries on unwithdrawn lands are referred by the General Land Office to the Geological Survey. The Survey thereupon renders to the Land Office a report on each case, classifying the land involved. If the Survey classifies the land as having no mineral, power, or reservoir value, questions concerning these values are considered as settled and the case goes forward if it is otherwise regular. If in a given case the Survey reports that the lands are mineral or that they have power or reservoir value the applicant is given 60 days within which to prove that the land is not of the character claimed by the Geological Survey but that it is in fact of the character originally claimed by him. If he fails so to prove, his application is canceled.

If the Geological Survey reports that it has not sufficient information to make a definite classification it furnishes to the Land Office whatever data it may have, which are placed in the hands of a member of the field service for field investigation and report. The report rendered is forwarded to the Geological Survey for further consideration, and a classification based upon it and other facts at hand is reported to the General Land Office. Under this agreement the records of the Survey are enriched by the data gathered by the Land Office field service and, on the other hand, the great amount of valuable information regarding the public lands on file in the Survey is made available to the Land Office in its administration of the land laws.

CLASSIFICATION BY THE GEOLOGICAL SURVEY.

HISTORICAL SKETCH.

Although the act organizing the Geological Survey definitely imposed upon the Director the duty of classifying the public lands, it was many years before the records of the organization contained a sufficient fund of information to be of great use in public-land administration. During its first quarter of a century the Survey devoted its energies almost entirely to gathering scientific data regarding the whole of the United States, and only within the last six or seven years has the immense fund of information so gathered been applied in a systematic way to the solution of public-land problems. During the early period there were perhaps but two practical applications of the Survey's work to land classification. The result of the first application was the segregation of reservoir sites under the act of October 2, 1888 (25 Stat., 527), to which reference has already been made. Congress in 1891 restored all the lands that had been segregated under this act except the areas actually needed for the construction of reservoirs, which still remain segregated as reservoir sites and are not subject to entry. The second application was connected with the administration of the reclamation act by the Geological Survey. Many withdrawals of lands to be included in reclamation projects were made by the Survey prior to the separation from it of the Reclamation Service. With these two exceptions the Geological Survey devoted its energies to gathering data rather than to applying the data gathered to the classification of public lands until the year 1906. Since that date the Survey has been actively engaged in land-classification work. The cooperative agreement whereby certain types of information are made available to the Land Office in its administration of individual

entries and selections has already been described. In addition coal lands are being classified and valued as rapidly as the funds at the disposal of the Survey will permit, and oil, gas, phosphate, and potash lands and lands valuable for water-power and reservoir sites are being temporarily withdrawn from entry whenever information justifying this action is obtained. It is proposed to explain here briefly the history of the classification undertaken with respect to each of these resources.

COAL LANDS.

In the years 1905 and 1906 the general public began to realize that large areas of valuable coal lands in the West had been obtained from the Government by means of agricultural entries. The frauds thus perpetrated were so great as to shock the public mind and to call for some immediate action to prevent further similar looting. Accordingly the President, on June 29, 1906, directed the Secretary of the Interior to withdraw from entry all valuable coal lands. The Survey had previously been making special studies of certain western coal fields and its geologists had assisted in unearthing some of the coal frauds. It was therefore prepared to submit a list of lands which should be withdrawn from entry, and on July 26, 1906, the Acting Secretary of the Interior withdrew from all forms of entry all the lands on the list submitted by the Survey. Other lists for withdrawal were prepared by the Survey during the summer and fall of 1906, and one very excellent list was prepared by the Forest Service. These withdrawals, being intended to prevent acquisition of coal lands under agricultural entry, were made in such terms as to prevent all forms of entry. However, on December 17, 1906, the form of all outstanding orders of withdrawal was modified to apply to coal entries only, so that the withdrawn lands became again subject to agricultural entries but were not subject to coal entry. Thus fraudulent acquisition again became possible and was prevented only by the activity of the field service of the General Land Office. On the other hand, purchase of withdrawn lands as coal land became impossible until after classification and valuation. From time to time other withdrawals from coal entry were made until the spring of 1909, when many of the outstanding withdrawals were restored to their original form and made effective against all forms of entry. Soon thereafter Congress passed the withdrawal act of June 25, 1910 (36 Stat., 847), and since that date coal withdrawals have prohibited all forms of entry except entries on certain classes of land which are exempted from withdrawal by that act and agricultural entries for surface rights only. The policy throughout has been to withdraw all lands on which there is a reasonable probability of the occurrence of coal, to examine these lands as rapidly as the funds

available will permit, and on the information gathered to base classifications, the lands found to be noncoal land being restored to entry and those found to contain workable coal being appraised at prices not less than the minimum prices prescribed by the statute.

For a time the withdrawals worked great hardship. The greater part of the lands thus withheld were not good agricultural lands, but the total acreage suitable for agricultural development was large. The situation was finally relieved by the passage of three acts providing for agricultural entry upon lands withdrawn or classified as coal lands, the Government retaining title to the coal deposits and the right to prospect for and remove them. These three acts are more fully discussed below under the heading "Separation acts" (p. 45).

The first regulations prescribing criteria for the classification and valuation of coal lands were approved by Secretary of the Interior Garfield on April 8, 1907. They provided for a maximum workable depth of 1,500 feet and a minimum workable thickness of 2 feet, all lands underlain by coals of less thickness or at greater depth being classified as noncoal land. New regulations were adopted February 19, 1908, and these were in turn superseded by those of April 15, 1908, under which, although the minimum thickness remained unchanged, high-grade coals were classified as workable to a depth of 3,000 feet and certain thicknesses of low-grade bituminous and sub-bituminous coals to a depth of 2,000 feet. Under all these regulations valuations were based on an estimate in which the number of beds, the thickness of the beds, and the depth of the beds below the surface were taken into account; but the methods of computing prices were such that, for example, a 20-foot bed was valued at no higher price than an 8-foot bed. On April 10, 1909, Secretary Ballinger approved a new set of regulations, drawn on entirely different principles. The minimum thickness was fixed at 14 inches and—a more important change—computations of value were based on the tonnage of coal in the land rather than on the number of beds. The maximum depth was retained at 3,000 feet. These regulations, while far in advance of those preceding, were nevertheless open to criticism because they took little account of certain economic and mining engineering features, such, for example, as the relations between lift and haul, between thickness and mining cost, and between minimum thickness and workable depth. A new set of regulations has just been made effective in which these features have been taken into account and the maximum depth for the highest-grade coals has been increased to 5,000 feet. The prices are based on tonnage, heat value, depth, and thickness. These regulations are given in detail elsewhere in this bulletin (pp. 96-97).

OIL LANDS.

The earliest withdrawals of lands containing oil and gas were made in order to protect oil operators from agricultural entrymen. In 1900 certain lands in Wyoming and California were withdrawn from agricultural entry on representations made by citizens of those States that the lands contained valuable deposits of oil and gas and should be withheld from agricultural entry pending a determination as to their content of oil. These orders and others of similar character were from time to time issued by the General Land Office. The first withdrawal recommended by the Geological Survey was made in 1907. For years the Survey had been doing geologic work in the oil fields of California. Its geologists, studying the conditions of the oil industry as well as the geology and occurrence of oil, early became convinced that unless preventive steps were taken a great amount of fraud would be perpetrated and oil development would be seriously hindered by attempts to obtain oil lands through nonmineral entries. The withdrawal of certain lands was accordingly recommended, and on August 15, 1907, the Acting Secretary of the Interior approved the recommendation and the withdrawal became effective. In 1908 several withdrawals were made in California for the same purpose, and a withdrawal was also made in the Caddo field of Louisiana pending an investigation as to possible means of preventing the enormous waste of natural gas then taking place in that field.

Within a short time it became apparent that the situation was only partly covered by withdrawing oil lands from agricultural entry. The inadequacy of the placer law and its inapplicability to oil lands was clearly recognized. The law was framed to apply to solid minerals; when applied to fluids, such as oil and gas, it at once led to many abuses. Drilling along the boundaries of one claim in order to draw off oil or gas beneath a neighboring claim forced activity in drilling which resulted in production far greater than the demands of the market. The requirement of discovery as a prerequisite to title also forced development and overproduction. It became more and more apparent that oil and gas should be disposed of in terms of barrels or cubic feet rather than in terms of acres. These considerations, together with the advisability of retaining a supply of fuel oil for the use of the Navy, caused the Geological Survey to urge the suspension of all forms of entry on Government oil lands pending the enactment of new legislation by Congress. In consequence Secretary of the Interior Ballinger on September 27, 1909, withdrew from all forms of entry, location, or disposition all public lands believed to contain valuable deposits of oil or gas. As information has since been obtained indicating other public lands to be valuable for these minerals, they also have been withdrawn from all forms of

disposition under the mineral or nonmineral land laws. Field examination has shown that certain lands so withdrawn are not valuable for their oil or gas deposits, and they have been promptly restored to public entry. In one State, Utah, the surface of the lands so withdrawn is open to agricultural entry.

A number of bills providing for the disposal of oil and gas deposits have been introduced in Congress, but none have yet been enacted into law, so that the petroleum withdrawals continue in force and new ones are being made as occasion arises. The need of the Navy for a supply of fuel oil has recently been more strongly recognized, the battleships last authorized being designed to burn oil exclusively. Fully to insure the Nation an adequate supply of fuel oil two naval petroleum reserves aggregating 68,249 acres and estimated to contain at least 250,000,000 barrels of oil have been created in the San Joaquin Valley fields of California, one under date of September 2, 1912, and the second under date of December 13, 1912.

PHOSPHATE LANDS.

Phosphate lands, like oil lands, are withdrawn because of the inadequacy of existing law to dispose of phosphate. Only within comparatively recent years has it been known that important phosphate deposits exist on the public domain, but as soon as such deposits were discovered conflicts arose between entrymen under the placer law and entrymen under the lode law. As a matter of fact neither lode law nor placer law is fitted to phosphate deposits, which occur as sedimentary beds interstratified with barren rocks in a manner identical with that in which coal occurs. The placer law provides for the disposition of all forms of deposit except rock in place. The western phosphate deposits are clearly rock in place. Moreover, some of them lie at great depth and are as difficult to mine as coal or any other solid mineral. It is clear that the placer law is not logically applicable to these deposits. Under the lode law a vein which outcrops within the limits of a claim may be followed to indefinite depths and distances so long as the end lines of the claim are not crossed. A phosphate deposit is essentially an interstratified bed, some deposits extending for many miles and being involved in great folds and undulations. The application of the apex law to such deposits would assuredly result in great confusion. For instance, if two sets or series of lode claims are located along the outcrop of a bed of phosphate that occupies a geologic basin and outcrops around its margin, one set of claimants on one side, the other on the opposite side, each set of claimants might be entitled to the bed throughout its extent from outcrop to outcrop. Thus the same property might be disposed of to two separate claimants, each of whom would have a good title. It is obvious that the lode law, under

which such a condition is possible, is not suited to the disposition of phosphate deposits.

Still another consideration led to the withdrawal of phosphate lands. Agriculture in the United States is comparatively young, so that the exhaustion of lands from long-continued use has not yet begun to be generally felt. In a large part of Europe, however, phosphate fertilization has become an economic necessity, and as a result the greater part of the phosphate mined in this country is being exported. It has seemed to many students of the situation that the United States should not part with a deposit so vital to its agricultural future. Pending consideration of this question by Congress, as well as the enactment of laws more applicable than the lode and placer laws, the first phosphate withdrawal was made by the Department of the Interior on December 9, 1908. Other withdrawals have been made from time to time as additional valuable deposits of phosphate have been discovered. Since the first withdrawal the known area of phosphate lands has been greatly increased by the explorations of the Geological Survey, and the reserves now include lands in Wyoming, Idaho, Utah, Montana, and Florida.

POTASH LANDS.

The agricultural industry of the United States has begun to feel the need for the rejuvenation of lands by the application of potash. All of this mineral heretofore used, in manufacturing as well as in agriculture, has been imported from Germany. A threatened termination of the supply from that source by the German Government lent acute interest to the question whether or not potash deposits are to be found in the United States, and on March 4, 1911, Congress appropriated \$20,000 for research and exploration for potash deposits by the Geological Survey. This appropriation was renewed the following year. Promising indications have been discovered, exploration work is being actively continued, and three areas have been found where the existence of potash salts warrants withdrawal of the lands. The first potash withdrawal covered one of these areas and was made on January 16, 1913. It is the present intention to recommend the withdrawal of all valuable deposits found and all lands in which there is a reasonable probability of the occurrence of valuable potash, these withdrawals to remain in force until Congress has provided more appropriate legislation than the existing placer law.

METALLIFEROUS MINERAL LANDS.

An unusual type of withdrawal, designated "Mineral-land withdrawal No. 1," was made in Arizona by the President on September 23, 1912. It covers an area in which investigations made by the Geo-

logical Survey show geologic conditions favorable to the occurrence of deep-seated deposits of copper. The deposits in this district are of such nature that no surface discovery, such as is required by the lode law, can be made. As a result valid locations can not be made upon the lands until valuable minerals have been discovered therein, either by deep drilling or deep shafting. There was danger that before either of these types of prospecting could be completed attempts would be made to obtain title to the lands by means of State selections or other nonmineral entries. Accordingly the President directed that the area be included in a withdrawal. By the terms of the withdrawal act the withdrawn lands are open to exploration and purchase under the mining laws, so far as they apply to metalliferous minerals. Thus the lands are reserved for exploration as to their metalliferous value but are not open to other forms of entry.

WATER-POWER SITES.

In messages to Congress during 1908 and 1909 President Roosevelt called attention to the danger of an uncontrolled monopoly of water-power development and to the desirability of preventing power sites on the public domain from falling into the hands of speculators and monopolists. As early as February 26, 1908, in a message transmitting a report of the Inland Waterways Commission, he advocated legislation providing for the leasing of such sites rather than their alienation. The report of the Inland Waterways Commission contains the following statement:

Wherever water is now or will hereafter become the chief source of power, the monopolization of electricity from running streams involves monopoly of power for the transportation of freight and passengers, for manufacturing, and for supplying light, heat, and other domestic, agricultural, and municipal necessities to such an extent that unless regulated it will entail monopolistic control of the daily life of our people in an unprecedented degree.

Since that time President Taft, Senator Burton, Secretaries Garfield, Fisher, and Stimson, and many others have advocated a revision of the laws pertaining to lands valuable for water powers and have especially urged the retention of their control by the United States.

In the winter of 1908 and 1909, under the direction of President Roosevelt and Secretary Garfield, a number of withdrawals were made covering streams in the Rocky Mountain and Pacific coast States on recommendation of the Reclamation Service. These orders of withdrawal covered wide areas, and as the best agricultural lands in the West are in the vicinity of streams, a great deal of popular discontent and criticism followed. Secretary Ballinger, soon after his appointment, ordered the restoration of all the withdrawn lands, and many such restorations were made, mainly in the latter part of

March and the early part of April, 1909. On April 28, 1909, Secretary Ballinger directed the Geological Survey to make an investigation of water-power sites on the public domain and to recommend as early as possible any withdrawals necessary to protect them pending the enactment of legislation to be recommended by the President. The first withdrawal under this order was recommended by the Survey on May 3, 1909, and approved by Secretary Ballinger on the following day. Since then many such power-site withdrawals have been made, so that at the present time it is believed that the greater number of the valuable power sites on the public domain are withdrawn from entry pending legislation by Congress for their appropriate disposal. The available information does not indicate that there is now in existence any all-inclusive, nation-wide water-power trust such as has been feared by students of the situation. Certain powerful and far-sighted interests have, however, made very determined attempts to acquire control of valuable sites in advance of the possibility of developing a market for the power that might be produced. The passing of these strategic points from public ownership would seriously impair the control by public authority of water-power operations, which are inherently monopolistic. As soon as the Survey obtains knowledge of such sites their withdrawal is recommended. Field examinations have shown that certain areas withdrawn were not so valuable as had at first been supposed and these have been promptly restored.

RESERVOIR SITES.

Reference has already been made to the act of 1888 (25 Stat., 527) and to the fact that certain tracts specially valuable for the construction of reservoirs were segregated under that act and still remain withdrawn pending their restoration by Congress. In its study of the water resources of the public domain the Survey found that attempts were being made to obtain possession of advantageous reservoir sites, not for the purpose of development but for some inferior use or for speculation. Pending legislation by Congress which would make such acquisition impossible a number of reservoir-site withdrawals have been made, the first one having been recommended by the Survey on January 13, 1911, and approved by President Taft on January 17, 1911.

PUBLIC WATER RESERVE.

In the great semiarid grazing areas of the West watering places are few and the range is, in places, monopolized by control of the water holes. It has been common practice for a stock owner to file some form of land scrip or State selection upon all the springs in a district and thereby to exclude all other stock owners from the dis-

strict as effectually as if he owned every acre of it. In most places the public range of the West is greatly overcrowded and the competition for possession of the water holes has been exceedingly bitter, with the advantage in favor of the large owner, on account of his greater ability to purchase land scrip. Exclusion from the watering places has ruined more than one stock grower and violence has not infrequently accompanied the struggle for their possession. This condition of affairs led members of the Land Office and of the Survey to urge that the watering places on the public range be retained in Government ownership and thrown open to the use of all comers. The possibility of the passage by Congress of a grazing law added to the advisability of such withdrawals. The present conditions on the public range are by no means satisfactory. They give undue advantage to the large stock raiser and are resulting in the deterioration and in many areas the ruin of the range. Several bills have been introduced in Congress providing for Government supervision of grazing under a leasing system. If such a law is passed it is highly important that a sufficient number of watering places to permit the administration of leases should remain in Government ownership. On March 29, 1912, public water reserve No. 1 was recommended by the Survey and approved by the President. Other public water reserves are being created as rapidly as field data can be considered.

WITHDRAWAL ACTS.

The early coal, oil, phosphate, and power-site withdrawals were made by the Secretary of the Interior in the exercise of his executive discretion and without specific authority granted by Congress. The right of the Executive Department to make land withdrawals has been established by numerous court decisions relating to withdrawals covering small areas, but as soon as general withdrawals of large areas were made interested parties began to question their validity. Many claimants asserted their belief in the department's lack of authority by proceeding in disregard and contravention of the withdrawals. This type of action was especially frequent in the oil fields of California and it early became apparent that, unless the validity of the withdrawals was clearly established, millions of barrels of oil would be taken from withdrawn lands while a decision was being obtained from the courts. Accordingly, Congress was urged to pass an act confirming the power of the Executive to withdraw public lands, and on June 25, 1910, a law was approved entitled "An act to authorize the President of the United States to make withdrawals of public lands in certain cases" (36 Stat., 847). That this act was merely confirmatory of powers already reposing in

the President and his cabinet is shown by the report of the Senate Committee on Public Lands, from which the following is quoted :

The power conferred upon the President by the proposed substitute is a power that he has possessed and exercised almost from the inception of our public-land system and is a power that he still possesses and exercises.

The power of the President to reserve public lands from sale and entry rests upon various statutes, upon numerous decisions of the courts, and upon long-established and long-recognized usage.

It is only lately that this power has been doubted and questioned, and the object of the proposed substitute is to make it definite and clear beyond all dispute that the President possesses this power of withdrawal.

Immediately after the passage of the act of June 25, 1910, Executive orders were issued by the President ratifying, confirming, and continuing in full force and effect all outstanding orders of withdrawal. Since that date all new withdrawals have been made in accordance with the provisions of this act and have been approved by the President.

The act of June 25, 1910, contains several provisions modifying preexisting practice. In the first place, it provides that lands which are embraced in lawful homestead or desert-land entries made prior to the date of withdrawal or on which valid settlement has been made and maintained shall be excepted from the force and effect of the withdrawal order so long as the entryman or settler continues to comply with the law. Thus the effect of an order of withdrawal on a preexisting homestead or desert-land entry depends on the initial and continued good faith of the entryman, rather than on the value of his land for purposes other than that under which his entry was made. The second important provision is that the rights of any person who at the date of a withdrawal order is a bona fide occupant or claimant of oil or gas bearing lands and who at that date is in diligent prosecution of work leading to the discovery of oil or gas shall not be affected or impaired by the order so long as diligent prosecution of the work is continued. It is to be noted that this provision makes the critical date that of the withdrawal order, even though that order was made before the passage of the withdrawal act. The department has held that what constitutes diligent prosecution of work leading to the discovery of oil or gas must be decided upon the facts in each case. It is safe to assume, however, that many of the subterfuges that have been commonly practiced for the purpose of holding claims will not be considered effective against the withdrawal orders.

Section 2 of the act provided that withdrawn lands should "be open to exploration, discovery, occupation, and purchase under the mining laws of the United States so far as the same apply to minerals other

than coal, oil, gas, and phosphates." There were two serious faults in this provision. For one thing, it did not permit the withdrawal of lands valuable for other minerals than the four enumerated. Thus, when interest in the potash situation became general and the desirability of reserving potash lands from entry was perceived it was not possible to make the desired withdrawals because of this provision in the withdrawal act. Furthermore, advantage was taken of this clause to locate valuable power sites as building-stone placers and to include oil lands of great value in placer claims located on comparatively worthless deposits of gypsum. These conditions led the President to urge upon Congress the amendment of the section by providing that withdrawn lands should be open to exploration and purchase under the mining laws for metalliferous minerals only, and on August 24, 1912, Congress so amended the original withdrawal act (37 Stat., 497). Public-land withdrawals now segregate lands from all forms of entry, location, or disposition except metalliferous mineral claims, preexisting homestead and desert-land entries and valid settlements, and oil placers on which work is being diligently prosecuted at the date of withdrawal.

SEPARATION ACTS.

The carrying out of the withdrawal policy for protecting the mineral and water resources of the public domain is in many cases rendered difficult and embarrassing by the agricultural value of the land withdrawn. If valuable water-power or reservoir sites were invariably valueless for farming, or if mineral and agricultural values could not coexist, no hardship would be imposed by and no retardation of development would result from the making of withdrawals. But some of the best farming lands in the West are underlain by coal or phosphate, and some are so situated as to be of strategic importance in power development. Any hindrance to bona fide home building or other agricultural development of the public domain is indeed unfortunate, but in order to protect the public's natural resources withdrawals resulting in such hindrance have been necessary. For certain lands the situation has been relieved by the passage of acts separating the surface right from the right to the underlying minerals. The first of these acts was that of March 3, 1909 (35 Stat., 644), which provides that persons who have entered or selected under the nonmineral laws lands subsequently classified, claimed, or reported as being valuable for coal may elect to receive patent to their lands by reserving to the United States the coal deposits and the right to prospect for and mine them. The act contains a provision for the indemnification of the surface owner for damages to his estate by prospecting or mining and a further provision that the owner of the

surface patent shall have the right to mine coal for his own use prior to the disposal of the coal deposits by the United States. This act granted relief only for entries or selections antedating withdrawal. The act of June 22, 1910 (36 Stat., 583), goes a step further with regard to coal lands and provides that homestead entries, desert-land entries, and Carey Act selections may be made on lands withdrawn or classified as coal whenever it is stated in the application that the entry is made to obtain title containing a reservation of the coal to the United States. In this, as in the previous act, provision is made for damages to the surface estate by prospecting or mining. The act of April 30, 1912 (37 Stat., 105), extends the act of June 22, 1910, to include State selections and isolated tracts.

An act approved August 24, 1912 (37 Stat., 496), provides for the entry or selection of withdrawn or classified oil and gas lands in the State of Utah, with a reservation to the United States of the oil or gas. The provisions of the act are similar to those of the coal act of June 22, 1910, and the classes of entries and selections permitted are the same as those in that act as amended by the act of April 30, 1912.

DESIRABLE NEW LEGISLATION.

In carrying out its function of classifying the public lands and in making its fund of information available in the administration of the existing land laws the Geological Survey has become acutely cognizant of the need for certain new legislation. The laws desired are primarily of two types and embody two fundamental necessities—first, the extension of the principle of the separation of estates, and second, the application of the leasing principle to the disposition of natural resources.

As has already been pointed out, the public lands can not be divided into classes each of which is valuable for one purpose only. Instead, the same tract of land may be valuable for two or more resources. In one tract—for example, agricultural land that is underlain by coal—both resources may be utilized at the same time without interfering with each other. In another tract—for example, agricultural land within a reservoir site—the land may be valuable for one resource only until it is utilized for another. In the first case the problem is so to frame the laws that no resource will be forced to await the development of the other. In the second case the problem is to permit the use of the land for one purpose pending its use for another without losing public control of the development of the second. In both cases the answer is found in a separation of estates. The extension of this principle, now applied to coal, to withdrawn and classified minerals and to the uses of water resources would permit the retention of the mineral deposits and power and

reservoir sites in public ownership pending appropriate legislation by Congress without in any way retarding agricultural development. Bills have already been introduced applying this principle to oil in other States than Utah and to phosphate in the State of Idaho. It is to be hoped that such bills will be passed and approved, or, better still, that a comprehensive act providing for the separation of the various estates will be introduced and enacted.

Nearly every student of the situation is agreed that the leasing system is far better than any other for disposing of natural resources. This conclusion is based partly on the logic of theoretical considerations, partly on the experience of other countries, such as the Australasian States, and partly on the fact that the leasing system is rapidly replacing all others in commercial practice in the United States. A single instance may be cited: Over 90 per cent of the oil production of the United States in 1911 came from leased lands. In the public interest leasing is to be preferred to sale for several reasons. In the first place, the sale of mineral lands at appraised values per acre presents problems of great difficulty and of uncertain solution, because of the number of factors involved. For example, in valuing coal lands under the present coal-land law or in valuing phosphate lands, should a similar law be enacted for that mineral, the items bearing on the value which should be fixed are so numerous, so difficult to estimate, and so variable that it is well-nigh impossible to arrive at conclusions which give the proper weight to all the factors involved. In valuing coal lands the end striven for has been to fix prices which shall be low enough to permit purchases for immediate development but which shall be high enough to prohibit speculative purchases or long-term investments. However, the proper consideration of transportation charges, market conditions, competing supply, and cost of labor is affected by so much uncertainty that it is difficult to fix a thoroughly satisfactory price for which lands should now be sold. When it is considered that the lands are to be sold in the indefinite future at the prices fixed now, the difficulties of the task become apparent. None of these difficulties would attend in the same degree the administration of a lease law under which the coal or phosphate would be paid for at a royalty per ton as mined. The fixing of the royalty would be very much simpler than the present task.

Attention has already been called to the inappropriateness of selling oil and gas by the acre. The distance within which oil and gas may be drawn off by a single well is not definitely known and is, of course, variable, but it is at least certain that a well drilled close to a property line will draw these minerals from adjoining portions of neighboring tracts. Under a leasing law the person required to pay for deposits of these minerals would not necessarily be the person

under whose holdings they originally occurred but the person from whose leasehold they were produced, and the price would be fixed by unit of quantity. The fairness of this plan is obvious.

The uncertainties as to market value of potash and other non-metals except coal, oil, gas, and phosphate make the payment of a sale price undesirable and the payment for the minerals as mined much more advantageous to the producer. In fact, one of the main arguments for the leasing as opposed to the sale system, not only for potash but for coal, oil, gas, and phosphate as well, is that instead of being required to advance the entire price of the land at the outset, the payments are made only as the mineral is produced, thus enabling the operator to begin operations with a much smaller initial investment. This is certainly advantageous to the small operator. Moreover, under a lease law the many uncertainties which enter into the fixing of sale prices would be eliminated, since only the quantity produced would be paid for.

Probably the present mineral laws are more satisfactory when applied to the metals than to the other minerals. Without doubt even here a lease law would effect a marked improvement on present practice, but if they were modified in three features the laws applicable to metalliferous lands would be reasonably satisfactory to the miner and to the public at large. In any event, the law of the apex should be abolished, the provisions regarding discovery should be modified, and the period for which a claim may be held without patenting should be limited. Regarding the first of these points there is little need for argument. Mining congresses and bar associations have alike recommended the repeal of the apex provision and shown conclusively the detriment which it is and has been to the mining industry. That it is possible to do away with it without resultant confusion is shown by the experience of British Columbia. One point, however, should not be overlooked—if the law of the apex is abolished the width of the claim should be increased in order to assure sufficient values to warrant the opening of a mine.

The requirement that mineral shall be discovered as a prerequisite to location is one that works undue hardship to those exploiting deep-seated deposits that do not crop out at the surface, such as those included in the mineral-land withdrawal in Arizona. Such deposits are by no means rare in certain mining districts of the West, and the law should be so modified as to provide either for some adequately safeguarded substitute for discovery or for the protection of the miner during the long and expensive prospecting which he must carry on before minerals can be discovered. Such protection would be best afforded by a provision for a prospecting permit of limited duration, to be granted only if the geologic conditions are at least moderately favorable for the occurrence of the mineral sought.

Under the law as it now stands a claim may be held indefinitely without an attempt to obtain patent, and so long as the annual assessment work is performed the claim is secure against adverse claimants. Until patent is issued no taxes are assessable by the State, and many producing mines refrain from patenting in order to avoid taxation. A limit to the number of years that a claim may be held pending the institution of patent proceedings would correct this abuse.

It is not only with relation to mineral deposits nor by comparison with a sale system that a leasing system is advocated. Leasing should replace the present permit system, under which rights of way across the public domain are granted for reservoir sites, power development and transmission, and irrigation works. Under the existing laws the right of way granted is either in perpetuity or is revocable in the discretion of the Secretary of the Interior. Both of these conditions are undesirable—the first because the resource passes forever beyond the direct control of the public, which thus becomes powerless to guard against misuse, disuse, or monopoly; the second because the capital which is required in the construction of such enterprises is not sufficiently protected. Between the grant in perpetuity, which inadequately protects the public, and the revocable permit, which inadequately protects the capital invested, lies the lease, which adequately protects both. By leasing rights of way for a fixed period of years absolute control would periodically return to the public, while the investor would be secure for a period long enough for his investment to return a profit.

If a lease law is to be adopted certain provisions should be incorporated in it, whether it is for a single resource or for all. In the first place the end to be attained is not revenue for the Government but is rather the retention of control in the public. It would be a long step backward to return to the early policy of using the public lands as a means of Federal revenue, and any lease law enacted should be so framed as to encourage development, prohibit speculation, and add nothing to the cost of the resource to the consumer. The States in which the lands are situated should be compensated for the loss of taxes which they would suffer from the permanent retention of the fee to natural resources in the National Government. Doubtless the simplest way to accomplish this is to provide that a certain percentage of net receipts from leasing shall go to the State in which the lands are situated. The term of a lease should be long enough to permit profitable investment and development. It should not be longer than is necessary to furnish an adequate return on the amount invested.

Whatever action Congress may decide to take regarding the natural resources now in public ownership should not be much longer de-

layed. The present withdrawals are a temporary expedient whose employment should be rendered unnecessary as soon as possible. It can not be economically advantageous to the country to have millions of acres of lands, valuable for petroleum, phosphate, or potash or for power or reservoir sites, absolutely segregated from all forms of disposal for an indefinite period. Some of the lands have already been so withdrawn for nearly four years. Congress should be fully informed concerning all the factors to be considered, but it should also act promptly.

CLASSIFICATION OF MINERAL LANDS.

FIELD METHODS.

DEVELOPMENT.

Since the United States Geological Survey was organized the methods it employs in its diverse field investigations have gradually become more refined and more precise. If a topographic map made by the Survey 20 years ago is compared with one of its recent maps the difference will be patent even to the untechnical critic, yet many of the important improvements adopted during that period do not appear on the map. The closer and more accurate triangulation net, the great increase in the numbers of intersected points and of level lines, and the general completeness of both vertical and horizontal control are not directly reproduced on the completed sheet, but they have been used in its preparation and give it far greater accuracy and expressiveness than the earlier maps. The methods employed by the engineers of the water-resources branch and by the geologists of the geologic branch have likewise undergone steady and consistent development.

Perhaps nothing in recent years has so directly stimulated the employment of more precise methods in field work as the requirements of land classification, and the development here is well exemplified in the work done by the coal geologists. The law under which coal land is classified, unlike the laws controlling the classification of lands containing other mineral resources, requires a valuation of the land. It is therefore especially necessary to trace the outcrops of coal beds with exactness and to fix their relations to the units of the public-land surveys by precise methods. This has led to the introduction of refinements that are not generally considered necessary in preparing a geologic folio or in determining the general relations of the formations in any region. It is perhaps worth while to trace a part of this development of the field methods employed in the classification of coal lands, as an example of a general improvement and as an introduction to a discussion of the methods now

generally used by the geologist in the solution of problems of classification.

The acts separating the mineral and agricultural estates of coal lands were not passed until 1909 and 1910, so that the withdrawals of coal land promulgated prior to that time prevented the initiation of both homestead rights and coal entry on the same tract. In order that this interference with agricultural development might be reduced to a minimum, the first examinations were directed toward the correction of the withdrawals by the prompt elimination from them of the noncoal land. The methods first used, therefore, were planned with the idea of covering large areas quickly and did not involve a marked departure from reconnaissance methods already in vogue, except that it became necessary to tie the investigations as closely as possible to such cadastral surveys as existed. One of the first methods employed at the beginning of the work of coal-land classification in 1906 and 1907 was that of retracing land lines. In doing this work the field men rode along the section lines established by the General Land Office, using the pocket compass to determine direction and horse pacing to measure distance. Coal outcrops along the section lines were mapped, the geology was studied in a general way, and a sketch of the topography was made.

In areas in which the absence of satisfactory land corners made it necessary to construct a map independently of the Land Office surveys a different method was adopted. By the use of a 15-inch plane table and an open-sight alidade a main or control traverse was run, completing a circuit of the field, distances being measured by intersections from points previously located and altitudes determined with an aneroid barometer. The topography and geology were mapped by means of a network of secondary traverse lines tied to the primary traverse. As the work progressed a more or less complete system of triangulation was established which could be used in adjusting the main plane-table traverse, and in turn the plane-table traverse served to check meander traverse. In running these meander traverses a pocket compass was used for obtaining directions, distances were measured by pacing, and elevations were determined by aneroid. The meander-traverse lines were plotted in the field as the work advanced, a small celluloid protractor being used for laying off angles and a scale graduated to correspond to the scale of the township plats being used for measuring horizontal distances. During the field work especial care was taken to locate whatever land corners existed, in the hope that these corners would serve as a basis for later adjustment of the township and section lines on the map.

These two methods probably represent fairly the general field methods in use during 1906 and 1907, in connection with classification of coal land. Some idea as to the speed attained in this work

may be formed from the statement that on an average a township (36 square miles) was completed by one man in four days. The following figures will also give some idea of the effectiveness of these methods for the purpose which they were designed to accomplish.

During the last six months of 1906 the total area withdrawn for examination was approximately 66,000,000 acres, and by the close of that year, as a result of the field examinations, approximately 2,000,000 acres had been restored to public entry. During 1907 there was an additional preliminary withdrawal of approximately 2,000,000 acres and by the end of the same year about 34,000,000 acres had been added to the restorations. Thus, of the 68,000,000 acres withdrawn during the first two years about 36,000,000 acres were restored as noncoal land as a result of the rapid methods then used. Had the Survey attempted a detailed study of these lands from the beginning, there would have been much undesirable delay in the restoration of large bodies of noncoal lands to entry. These early relatively inexact methods were therefore well adapted to the ends they were designed to accomplish.

The principal areas of coal land having been outlined by reconnaissance surveys, attention was next turned to more improved methods of field work to meet the constantly growing need for better and more detailed classification. The reconnaissance method was then replaced by that in which plane table and telescopic alidade are employed. The most satisfactory alidade, which was designed by one of the geologists engaged in the classification work, is a small instrument carrying a telescope fitted with cross wires for stadia work and a vertical arc for determining differences of altitude.

The details of method used in plane-table mapping are varied according to the topography and the forest conditions of the area mapped, as well as according to the condition of the land survey. In an area where there have been no land surveys or where those that have been made are very poor, the triangulation or station method is preferred, but stadia work only is practicable in certain areas—for example, heavily wooded districts or regions cut by deep, narrow canyons. Either method, however, gives excellent results, for by either the coal outcrop is actually traced in the field and the exact horizontal and vertical positions are determined for every observation. In connection with these precise locations full data are procured on the character of the coal. If the region is undeveloped and no coal mines or prospect pits are available for examination, openings are made and sections are measured wherever such work is necessary to give adequate data for classification.

Perhaps the most detailed work that is now being done in the coal areas is that carried on in those districts where the geologist works in conjunction with the topographer. This method results in

a reduced cost of the work and a great degree of accuracy in location. In work of this kind the geologist usually examines the territory in advance of the topographer, prospecting the coal bed and carefully marking by means of flags all prospects and coal outcrops which he desires the topographer to locate. The topographer, in the course of his mapping, determines both the horizontal and the vertical positions of all points flagged by the geologist. This work is done instrumentally and with great accuracy, the probable limit of error in the horizontal location of any point being less than 20 feet and in the vertical location less than 5 feet. With many points on the outcrop thus accurately located, underground structure can be determined with a degree of accuracy that has seldom been attained in geologic work.

With this preliminary statement, it is proposed to set forth briefly some of the methods now in use under the various conditions that confront the geologist who is assigned to the task of making a mineral classification of a specific area.

A. If he is required to make a detailed survey, he will find one of the following conditions existing:

- (a) A topographic base is available.
- (b) A base map is not available but must be made.
- (c) A topographic base is not available and is not essential, the land survey sufficing as a base map.

B. If he is making a preliminary survey only he will use reconnaissance methods.

DETAILED SURVEY.

METHODS USED WHEN A TOPOGRAPHIC BASE IS AVAILABLE.

It is desirable that the examination of the mineral deposits in regions of especial economic importance be based on an accurate topographic map prepared in advance of the geologic examination. Such a map, on which are shown the relief by contours of appropriate intervals, the position and character of the drainageways, and the location of land corners, roads, houses, and the bench marks and triangulation stations established by the topographers, enables the geologist to determine by surveyor's methods the location of the numerous points at which he makes observations, with a minimum expenditure of time and with a degree of precision adequate to the scale of the map and the work in hand. The scales which are generally used by the Geological Survey in work of this character are about $1\frac{1}{2}$ or 2 inches to the mile, with contour intervals of 10, 20, or 50 feet. The degree of accuracy attained in work on such maps is represented by the width of a carefully drawn pencil line, or less than 20 feet for locations where refined plane-table methods are employed—for example, along the outcrop of the coal, oil sand, or phosphate bed—and by a

somewhat variable larger figure for locations requiring a less degree of accuracy and made with less precise instruments. The actual elevation of observations along the outcrop of the valuable bed is determined with surveying instruments, so that the error is rarely in excess of 5 feet, an amount which is practically negligible in mountainous regions. In special cases, however, a higher degree of precision is attained.

The information collected by the geologist in the field relates to the quality and thickness of the economic deposit, the position of its outcrop relative to legal subdivisions, and its depth and accessibility where covered. He maps the actual position of the outcrop of the coal bed, oil sand, or phosphate bed by making careful locations at many points, as described above, and where possible determines the attitude of the bed by many careful dip readings with a clinometer or by computation from its elevation at several points. He also maps the position of the top and bottom of the overlying and underlying beds, so that the completed map shows the actual area covered by the outcrop of beds of sandstone, limestone, conglomerate, shale, or such other rocks as may be present in the region. He further determines the attitude of these rocks and collects typical samples and fossils which serve to determine their relative age. Part of this information is represented on the map by symbols whose significance is expressed in the accompanying legend, and part is recorded in suitable notebooks for use in the preparation of reports. This information is put together in a tabular form showing the normal arrangement of the beds, which is technically spoken of as a columnar section. Such a section shows the normal distance through the strata from the economic bed to the top or bottom of any one of the constantly related overlying or underlying beds, and it is used in combination with the data on the outcrop of the overlying rocks in working out the theoretical underground position of the bed. The methods of making the computation are explained in detail in the following discussion of the examination of areas for which a topographic base is not available.

The deposits of present economic importance or of promise for the future are sampled at many points where the natural exposures are favorable and in other places by means of pits, trenches, or drill holes. All the samples from any one deposit are taken by a uniform method designed for that kind of material.

METHODS USED WHEN A BASE MAP MUST BE PREPARED.

In the detailed geologic study of an area it is usually necessary to construct a map which shall place before the eye of the geologist all the available information concerning the area in such space that it can be viewed as a whole and the correct relations of details comprehended as they could not be on the ground. Such a map to be of

the greatest value should show not only geology but surface relief and the positions of streams, roads, and houses, with the legal subdivisions of the public-land surveys, in order that the geology may appear in its true relation to surface features. The construction of a map giving such details is, strictly speaking, the work of the topographer rather than of the geologist, but the latter may be called upon to examine an area for which no adequate base map has been prepared and he is therefore obliged to construct a map, either contoured or plain, on which to record the geology. Such a map may be made by the use of various instruments, perhaps the most satisfactory in both accuracy and speed being the plane table and the telescopic alidade. These instruments used with a system of triangulation are particularly adapted to open country in which signals can be seen for considerable distances. In areas where, for various reasons, it is impossible to sight distant signals the method of stadia traverse is employed, the same instruments being used in conjunction with the stadia rod.

In constructing a map by a system of triangulation, the procedure is briefly as follows:

A base line is measured and the plane table is set up at one end of it and properly adjusted so that one edge of the table lies in a north-south line. The base line is then plotted on a selected scale, usually from 1 to 4 inches to the mile, and sights are taken and lines drawn in the direction of monuments on prominent hilltops. The plane table is then transferred to the other end of the base line and correctly oriented by back sight. Sights are then taken and lines drawn in the direction of the monuments sighted from the first station. The intersection of the two lines drawn in the direction of each monument establishes its location in relation to the base line as indicated on the map. After the various signals are located in a certain area the plane table may be set up at any point whose location is not known, and after it is approximately oriented by compass sights may be taken to the points already located and the position of the instrument determined by lines drawn from the locations of these signals on the map. These lines should exactly meet at a point. If they do not so meet there is some inaccuracy either in the previous work or in the orientation of the plane table. It is thus possible to keep a close check on the work and points may be located as accurately as the scale of the map allows.

On a scale of 2 inches to the mile a distance of 10 feet would be represented by the width of a fine pencil line, and it is not possible to plot a distance of, say, 5 feet. A distance of 10 or 15 feet, however, is perceptible, and locations may be accurately made within such distances. If the scale is increased to 4 inches to the mile the error in the location of a point should not exceed 10 feet. After the primary signals are established over the township the base map

and the geologic map may be constructed simultaneously—that is, in tracing the exposures of some particular bed, such as a coal or phosphate bed or an oil sand, the geologist may sketch in the roads or streams or topographic features near which his instrument happens to be set.

In mapping a particular area geologically as many points are located as are necessary for the degree of accuracy desired on the map. In critical parts of an oil field, where all dip readings are located by the plane table, observations may be taken every 400 or 500 feet, but in parts of the area outside of the probable extent of the oil pool dip readings taken every mile may be amply sufficient if the dip is regular. Places at which fossils are collected are marked on the map and also places at which rock specimens and coal, phosphate, or oil samples are taken, as well as localities where sections of the beds or other geologic observations are made. In the construction of such a map any land corners that may be found are located from the signals previously established, just as rock outcrops and other features of interest are located. The land net is afterward drawn in from the corners which have been found, and any inaccuracies and irregularities in the old surveys will thus be detected. In land classification the tracts are always described with reference to these surveys, so it is very essential to locate as many of the corners as possible in order that the position of the land lines may be accurately known. The time required to construct a map of this kind varies greatly with the nature of the country and the character of the geology. One man can, as a rule, establish primary control over a township in one to three days, the time required being dependent entirely on the number of locations made and the nature of the country traversed.

The method of locating important rock outcrops by stadia traverse may be successfully employed in conjunction with location by triangulation, or it may be used alone without triangulation. In running a traverse with stadia the instrument man can not work alone but must employ the services of a rodman. The plane table is set at some known point, the stadia rod is held on the point whose location is desired, and the direction from the point occupied to the other point is drawn on the map by means of the alidade. The distance is read by means of the stadia and platted on the map by the use of a scale, in the direction already recorded; this locates the second point. The instrument is then transferred to a third point, the location of which is determined by a reversal of the method used in locating the second. The rod is then moved ahead and the process is repeated. Such a method is most useful when a coal or phosphate bed or an oil sand is to be outlined in great detail or when the work is done in deep

valleys or canyons from which it is difficult to sight triangulation signals.

In the above description no mention has been made of the method of determining elevations, which in much of the work are of great importance. With a telescopic alidade the angle of elevation or depression from one point to another can be accurately determined. This angle being known and the distance between the two points being measured with a scale from the locations of the points on the map or by reading a stadia rod, the problem resolves itself into the solution of a right-angle triangle in which one side and one of the acute angles are known, the side to be determined representing the vertical distance between the two points, or, in other words, the difference of elevation between them. The altitude of a starting point being known or assumed, it is possible to calculate the altitude of any number of points in any direction from it. Elevations determined by this method are not absolutely exact but are of sufficient accuracy for most purposes of geologic mapping. In ordinary practice they are correct within 5 or 6 feet, but with certain refinements of work the error can be reduced to 1 foot or even less.

It is advantageous to represent on a map in some manner the form of the rock folds, which may or may not correspond to the surface relief. Ordinarily surface relief is represented on a contour map by lines drawn to indicate definite elevations above sea level, one line, for example, at 4,000 feet, the next at 4,100 feet, the next at 4,200 feet, and so on. These lines not only show the configuration of the surface but also give approximately the elevation of any point within the area thus mapped. It is possible to contour in the same way the surface of an oil-bearing sandstone or a coal or phosphate bed which has been bent into a fold. Such contours are known as structure contours. They bear no necessary relation to surface relief. In fact, a valley may occupy the axis of an anticline or a ridge the axis of a syncline.

Sedimentary beds deposited one above another during a period in which there has been no earth movement are parallel—that is, if one sandstone so deposited is 2,000 feet above another at one place it is probably 2,000 feet above the other 1 mile or 5 miles away. If since their deposition the beds have been tilted from the horizontal, the dip of a bed at the surface in general represents the dip of the beds below it. If a certain oil-bearing sandstone dips 5° E. where it appears at the surface and overlying beds of the same formation outcropping east of the exposure of the first bed also dip 5° in the same direction, it is probable that the first bed and all intermediate beds have the same dip in this area also. A dip of 1° is equivalent to about 92 feet in a mile, and a dip of 5° to about 460 feet in a mile.

Therefore a bed that dips 5° E. under a horizontal plain is 460 feet beneath the surface at a point 1 mile east of the outcrop.

If it appears from surface exposures of the overlying rocks that the dip is not constant, allowance must be made for the variations in the calculation. In areas in which drilling has been carried on the records of the wells are invaluable as giving accurately the depths of beds beneath the surface, thus checking the deductions from surface evidence.

The locations of structure contours are based on a variety of data. If a well whose altitude at the surface is 4,000 feet strikes an oil sand, for example, at a depth of 1,000 feet, it is evident that the 3,000-foot contour on the oil sand passes through the location of this well on the map. If the rocks dip toward the east and a sandstone known to be 2,000 feet above the oil sand outcrops half a mile east of the well at an altitude of 4,500 feet, the oil sand should be at this point 2,500 feet above the sea, or, in other words, the 2,500-foot contour should pass through the location of this sandstone outcrop on the map. If the dip of the rocks exposed at the surface is constant between the mouth of the well and the outcrop of the sandstone it indicates that probably the oil sand dips regularly to the east between these points, and the contours of 2,600, 2,700, 2,800, and 2,900 feet may be spaced evenly between the 2,500-foot contour at the sandstone outcrop and the 3,000-foot contour at the well. Should the dip, as indicated by the surface exposures, be irregular between the two points, the contours are spaced accordingly, being placed nearest together where the dip is greatest and farthest apart where the dip is least.

After a structure-contour map is completed it is possible to estimate from it the depth of a bed of economic importance at any required point, if the surface altitude of the point is known.

METHODS FOLLOWED WHEN THE LAND OFFICE SURVEY AFFORDS A BASE MAP.

More than half of the coal land still owned by the Government lies in the rather sparsely settled plains region which has not been mapped topographically but has been covered by the cadastral surveys of the General Land Office. For such land, a topographic map not being essential, a method of survey different in some ways from those described above has been adopted. Plane table, telescopic alidade, and stadia rod are used as in the other work, but the results of the surveys made by the General Land Office are used as a base for the work, and the township forms a unit, the results being sufficiently detailed and accurate to permit classification by legal subdivisions. As previously stated, some of these surveys are not accurate, but they are official and in general they provide a suitable base

for the survey. Locations and measurements are therefore accepted as recorded on the Land Office plats unless the field work proves them to be in error.

If a preliminary examination of the township to be surveyed shows that it contains only a few isolated outcrops of coal beds and no continuous exposures, the geologist locates the outcrops by triangulation and sketches their inferred locations. For the triangulation two convenient land corners are selected from which to begin work, and for a base line the distance given on the land plats is used, it being assumed that this distance has been correctly determined in the land surveys. The corners thus selected are located on a plane-table sheet, and from them other triangulation stations are established over the field and their elevations determined by vertical angles, as already described. After enough points to control the work in the township have been established the geologist makes a detailed examination of the coal. He goes to each outcrop and digs or bores through the bed to learn the thickness of each bench of coal and of each parting and to obtain samples of the coal for study or analysis.

After the bed has been examined and the dip of the strata has been measured the position of the outcrop is located on the plane-table sheet and the elevation determined.

The examination of the coal bed is most important. It must be made carefully and accurately. Each geologist who surveys coal land is told that "every inch of the bed must be critically examined." If the inspection shows that the coal may contain more than the normal percentage of impurities a representative sample is selected and taken to camp, where an ash test is made with a small portable chemical outfit. If there are mines in the area a sample is procured according to the prescribed method (see p. 106) and is sent to the chemical laboratory for analysis. The strata in which the coal is found are also carefully examined to obtain any additional information they may give concerning the depth and continuity of the coal beds where they are covered.

The triangulation method of location described above suffices in areas where there are only a few small outcrops of coal beds, but in townships which contain more than a few outcrops or in which the beds can be traced the outcrops must be accurately located by stadia traverse in addition to the triangulation. If the triangulation and stadia work are done properly, locations should be correct within 20 feet and elevations within 5 feet.

In work of this kind the surveyor traverses the outcrop of the coal bed and with the aid of an assistant and instruments he locates points at short intervals along the line of outcrop and sketches its position between these points. All such locations are tied to land

corners accurately with instruments, and the elevation of each point is ascertained, so that the underground relations of the bed can be determined.

The number of sections measured along the outcrop of the bed depends on the local conditions. If the bed is variable it must be examined at short intervals, but if it is regular the measurements may be made farther apart. Some records show measurements only 50 feet apart, whereas others are half a mile or more, though a shorter distance is recommended. There is no definite number of measurements to the township. In some townships few are made, whereas in others there are as many as a hundred.

At the same time that the geologist is examining the field he procures any information which may have been obtained by miners, prospectors, well drillers, or others making excavations. Such information ordinarily consists of records of wells, drill holes, and mine shafts, mine maps, both exterior and interior, records of production and use, etc., and is of great value in the proper classification of the land.

This method may be applied equally well to materials other than coal if they occur in or in a definite relation to stratified beds, and with modifications it may be and is adapted to less regular deposits of metalliferous minerals. Its chief application, however, in actual Survey practice is in the coal fields of the plains region, where the recent and more accurate Land Office plats are available as bases.

RECONNAISSANCE SURVEY.

Reconnaissance surveys are ordinarily only preliminary and those made for purposes of classification are intended to determine the general distribution of the mineral deposits in areas which have not been described by geologists or which may have been examined only casually or with some other problem in mind than that of discovering minerals of economic value. If no reliable information is at hand concerning an area containing public land, a geologist makes a reconnaissance to determine the best method of work to be followed if minerals are found.

The method of reconnaissance varies with the character of the country to be examined. If the country is suitable for the use of the plane-table method of surveying, the geologist uses that method. He proceeds in the manner already described but on a smaller scale and with less detail. If the country can be readily crossed and little accuracy is required, the geologist starts with an assistant and travels by buggy to the points to be examined. He determines his location from traverses based on hand-compass readings to give direction and on counted revolutions of the buggy wheel to give distance. These traverses are tied to known points wherever possible, and the inter-

mediate locations are adjusted from them. If the country can not be crossed in a vehicle, the geologist goes on horseback or on foot and determines direction as before and distance by counting the number of paces taken by horse or man. This method gives considerable accuracy in location and provides an adequate basis for determining the general mineral or nonmineral character of an area.

State or county maps furnish locations for the geologist on some reconnaissance trips. When working with such a map he starts from a town, post office, or some point shown on the map and proceeds toward some other point also shown. To obtain his location at intermediate points he estimates distance and direction and records his observations with regard to the estimated locations. This method is seldom used, because of its inaccuracy, and it is never used to procure final data for land classification. It was found applicable to conditions in one of the Western States where large areas were withdrawn on the basis of a report that later proved to be erroneous. In this State the general reconnaissance proved the area to contain no coal of value; hence no careful examination was required.

PUBLIC-LAND SURVEYS.

Public-land surveys made by the General Land Office result in the official township maps which are the basis of all land titles and to which, therefore, all data on land classification must finally be adjusted. The system now in use was adopted in essentially its present form in 1785. Under this system a certain initial point is first selected through which a north-south line, called a principal meridian, and an east-west line, called a base line, are run. At successive intervals, usually 24 miles, north and south of the base line standard parallels or correction lines are established parallel to the base, and similarly at intervals east and west of the principal meridian guide meridians are established. Because of the convergence of meridians toward the poles these guide meridians are not parallel to the principal meridian but approach it toward the north. In order to correct this narrowing the guide meridians are offset at each standard parallel and started anew northward at their original distance apart. The quadrilateral thus defined is subdivided into townships, each approximately 6 miles square, and each township in turn is divided into 36 sections 1 mile square. Each section is further subdivided into quarters, and each of these is held to contain four 40-acre tracts, or quarter-quarters, the smallest commonly recognized legal subdivision of the public-land system. Appropriately marked monuments are set at all township and section corners and at the middle points of the side lines of sections, thus indicating the limits of the quarter sections. Posts indicating the quarter-quarters are not set, but this unit, and indeed in special cases smaller units of

10-acre or even $2\frac{1}{2}$ -acre tracts, may be recognized in land classification.

This general plan, where properly carried out, is simple and effective and has furnished a satisfactory basis for land records and titles for more than a century and a quarter. Its execution, however, has not in all localities been satisfactory. For a great many years the work was done by contract under State surveyors general, despite the repeated and urgent requests of many Commissioners of the General Land Office for authority to do the work directly. In earlier years the contracts were sometimes distributed as rewards for political services, and the inspections were not always of a character to guard against the acceptance of inadequate surveys. Some of the contracts were obtained by honest men who did their work well, but others fell to inefficient or dishonest contractors who made poor surveys or none at all, although they prepared township plats which were submitted under oath as to their accuracy and which were accepted. In the older fraudulent surveys of this type all sorts of errors and omissions are encountered. In certain localities no monuments can be found and there is every reason to believe that the lines were never run. In other localities the work was done so carelessly that the corner posts are found far from the proper locations. The General Land Office, under the contract system, required that monuments were to be made of stone wherever it could be procured, but the use of wooden posts was permitted in other places. In some localities where advantage was taken of this permission the stakes set were so small or so poorly fixed in position as to constitute merely a nominal observance of the requirements, and many of the stakes thus set have disappeared.

Within recent years the Land Office has adopted the plan of marking corners permanently by deep-set iron posts and has been authorized by Congress to make surveys directly instead of by contract. These modern surveys provide a highly satisfactory basis for land titles, and some of the special surveys made on the Indian reservations by a combination of cadastral and topographic methods are models of complete and satisfactory base mapping.

For purposes of land classification it is imperative that the data procured by the geologist shall be tied to the land net because his classifications must be expressed in terms of the public-land surveys. Furthermore, these identifications must be exact, because it may occasionally be necessary to estimate values of the public lands in tracts of 40 acres, 10 acres, or even $2\frac{1}{2}$ acres. It is obvious that in such cases the land lines must have been accurately run and the corners sufficiently well established to permit undoubted identification. In a few places classification has been impossible because the land lines could not be found and the official surveys could therefore not be identified.

PREPARATION OF DATA FOR CLASSIFICATION.

The geologist, on returning to the office from a field examination of land for the purpose of classification, informally presents to the appropriate section of the board a general outline of his work, the area covered, and the problems met. Thereupon the section decides the particular form of map and report desired. The essential factor in determining in just what form the data shall be submitted is the requirement that all pertinent facts determined by the field investigator shall be recorded and that the finished report shall be as accurate as the field work in location and interpretation. The importance of accuracy and completeness becomes apparent when it is realized that the record once submitted must form the basis not

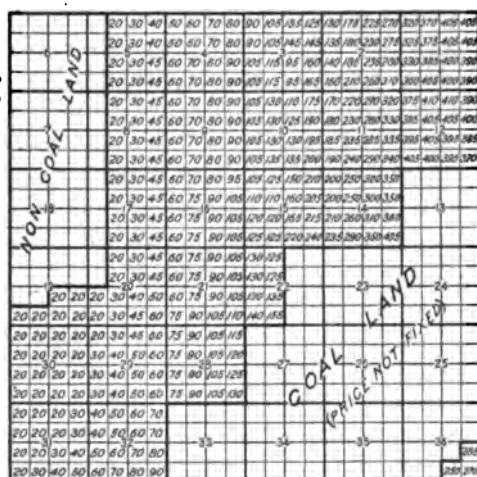
Resurvey T. 19 N., R. 105 W. of the Sixth P.M., Wyoming

Coal land price
not fixed because
General Land Office
records show it to be
in private ownership

Replacing plat
transmitted by
Geological Survey
September 8, 1909

Large figures
give price in
dollars per acre

Coal land within
15-mile limit



Acres
Coal, priced 13,819
Coal, not priced 6,534
Non coal 2,775
Total 23,208

As given 1,773,289
Minimum 276,381

I classify and
price the land
in this township
as shown person
J. D. Dyer
DIRECTOR

U.S. Geological Survey
May 28, 1910

FIGURE 1.—Township map showing classification and valuation of coal lands.

only for the classification of the land as mineral or nonmineral, a classification which may affect the interests of a large number of people, but also, in the case of coal land, for valuations aggregating millions of dollars. As an example, a copy of a township classification and valuation plat as transmitted to the General Land Office is given in figure 1. In June, 1912, private individuals purchased from the Government sec. 12 of this township, for which they paid the classified price as shown, amounting to over a quarter of a million dollars.

In general the data are compiled by the field geologist from his original maps and notes in two forms. The first consists of a small-scale map with an accompanying general report presenting the results of a study of the whole field. In this report the geologist discusses the stratigraphy and structure of the field as well as the oc-

currence of economically important minerals. On the map accompanying this report most of the finer details are omitted and only geologic formations and the outcrops of coal, phosphate, or oil sands are shown. The general report on a field contains a description of all that is known of the physical and chemical properties of the minerals occurring in that field. This report then serves as a basis for a set of general minutes, in which the appropriate section of the board outlines the application of the regulations governing the classification of lands containing those minerals to that particular field. After the general report has been considered by the proper section and the general minutes have been written, the field geologist prepares the classification data and in the case of coal land makes the valuation, under the immediate supervision and with the assistance of some member of the coal section of the board. Later the record is reviewed and passed on in detail by the entire section. Each 40-acre tract, and sometimes even each $2\frac{1}{2}$ -acre tract, is considered individually and all facts affecting its classification as mineral or non-mineral are weighed. A report of the proceedings of the section for each township is prepared, giving in detail the result of the classification and the reasons therefor. This report becomes part of the permanent records of the land-classification board.

Detailed reports on each township examined, with accompanying large-scale maps, constitute the second form of data. These are prepared in addition to the general report for all areas on which the smaller-scale map will not suffice for classification. On these large-scale township maps every feature that is possible of cartographic portrayal is represented—the outcrops, dips, and measured thicknesses of all coal or phosphate beds or oil sands, all mines, prospects, or lodes, the location of these features with respect to established land lines, and, if essential, the topography of the surface. Each map is supplemented by a description which gives the dates and methods of field work, the condition of land surveys, the proximity to railroads, and a discussion of the geology. In the valuation of coal land all calculations by which the price per acre for each tract has been derived are given in detail.

These reports and maps are all permanently mounted, arranged in order of State, range, and township in loose-leaf locking binders, and filed in fireproof steel cases. As new information is acquired, from whatever source, with regard to the mineral character of any township, it is added in its proper place in the binder. Such information consists of reports from field agents of the General Land Office, data obtained by members of the Geological Survey on subsequent examinations, affidavits of public-land claimants, and other matter. The original field sheets and notebooks are likewise de-

posited in the files of the land-classification board and are always readily available for use. Card indexes are maintained covering both sets of files.

COAL LANDS.

PURPOSE OF CLASSIFICATION.

By act of March 3, 1873, Congress provided for the sale of coal lands belonging to the United States, specifying the conditions of sale and the minimum prices. To carry out the act it is necessary to determine, first, what lands are coal lands (classification), and second, at what price they shall be sold (valuation). To give uniformity to Executive action in this work certain rules have been prepared by the Geological Survey and approved by the Secretary of the Interior under the title "Regulations for the classification and valuation of coal lands." These regulations provide exclusively for the classification and valuation of coal lands and are not to be confused with the regulations providing for the disposition of coal lands issued by the Land Office under the title "Coal-land laws and regulations thereunder." It is the province of the Geological Survey to determine what lands are underlain by coal within the limits set by the classification regulations, and to it has also been assigned the work of valuing the lands classified as coal land. Classification and valuation must follow three antecedent steps—(1) the adoption of regulations formulating the principles and practice which are to govern classification and valuation; (2) the field examination to determine the presence, position, quality, and other features of the coal in the land; (3) the assembling of the field data in such form as to facilitate the work of classification and valuation by making possible the simultaneous consideration of all the facts. Finally, classification and valuation involve a consideration of all the known facts to determine what legal subdivisions of land are coal lands under the regulations and at what price they shall be sold.

Preliminary to the detailed consideration either in the field or office of any area believed to contain valuable coals the lands are withdrawn from entry under the authority of the act of June 25, 1910 (36 Stat., 847), as amended by the act of August 24, 1912 (37 Stat., 497). A typical coal-land withdrawal order is appended with the accompanying letter of transmittal:

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
Washington, January 21, 1913.

The honorable the SECRETARY OF THE INTERIOR.

SIR: Information on file in the Survey indicates that the land listed below contains valuable deposits of coal, and I therefore recommend the submission to

the President for appropriate action of the following order of withdrawal, involving 1,600 acres.

Very respectfully,

Geo. Otis Smith,
Director.

JANUARY 28, 1913.

Respectfully referred to the President with favorable recommendation.

Samuel Adams,
Acting Secretary.

ORDER OF WITHDRAWAL.

Coal-land withdrawal—Montana No. 10.

Under and pursuant to the provisions of the act of Congress approved June 25, 1910 (36 Stat., 847), entitled "An act to authorize the President of the United States to make withdrawals of public lands in certain cases," as amended by act of Congress approved August 24, 1912 (Public No. 316), and subject to the provisions of the act of Congress approved June 22, 1910, entitled "An act to provide for agricultural entries on coal lands," as amended by the act of Congress approved April 30, 1912 (Public No. 141), it is hereby ordered that the following-described lands be, and the same are hereby, withdrawn from settlement, location, sale, or entry and reserved for classification with respect to coal values:

Montana meridian.

T. 3 N., R. 3 E., sec. 25, NE. $\frac{1}{4}$, S $\frac{1}{2}$;
sec. 26, SE. $\frac{1}{4}$;
sec. 35, E. $\frac{1}{4}$;
sec. 36, all.

Wm. H. Taft,
President.

JANUARY 29, 1913.

METHODS OF CLASSIFICATION.

PRINCIPLES INVOLVED.

In preparing the regulations for classification three principles are paramount: (1) The regulations must be based on demonstrated facts or on well-founded and generally accepted inferences; (2) they must be based on all the stable, permanent factors involved; (3) they must be as definite yet withal as simple as possible. Ideally the regulations should be so simple that anyone at all acquainted with the subject could correctly apply them, and they should be so definite as to admit of little or no disagreement in interpretation. Neither of these ideal requirements can be realized.

The workability of coal at a given point to-day depends on factors of two types. Those of the first type—such as quality, thickness, and depth—are intrinsic; those of the second type—such as railroad transportation and markets—are extrinsic. To-day the extrinsic factors may determine absolutely the commercial workability of a bed of coal at any locality. A coal bed 75 miles from a railroad and 50 miles from the nearest town, no matter how valuable it may be some day, has to-day a value that is purely prospective, depending on an unknown factor—the time when transportation shall

reach it. A new railroad may "make" a coal-mining district by opening new markets or may "break" it by bringing in competition that it can not meet. To be stable, therefore, the regulations must be based directly on the intrinsic factors involved. Tracts classified as noncoal land are disposed of as such without further question as to their content of coal. Classification should therefore anticipate and assume the ultimate coming of conditions favorable for mining and marketing any coal if the coal is otherwise workable.

If an 18-inch coal of a certain grade occurring under certain conditions is workable in Missouri to-day, hundreds of thousands of tons being mined yearly, it would appear to be a reasonable assumption that a coal of like thickness and quality occurring under similar conditions elsewhere will be workable some day and should therefore be classed as a workable coal; especially does this assumption appear reasonable when it is considered that everywhere the tendency is to extend the limits of workability. Coal mining has nearly always been conducted on a very close margin. In any new field—and most of the coal fields of the West to-day are new—only the most accessible, thickest, and best of the coal beds can be worked at a profit. Twenty years hence the most accessible coal will have been largely mined out and mining will be done on coal that is a little less accessible and that costs a little more to mine and that necessarily will sell at a little higher price. This higher price will permit the mining of other coal—a little thinner and a little poorer—which could not be mined profitably to-day, and the process will continue until all coal within minable limits is exhausted. The regulations attempt to define what these minable limits are, not in view of the conditions that may exist as the coal supply approaches absolute exhaustion, but in view of actual practice to-day under favorable conditions of transportation and of market.

FACTORS INVOLVED.

ESSENTIALS OF WORKABILITY.

The workability of any coal will ultimately be determined by two offsetting factors—(1) its character and heat-giving quality, whence comes its value, and (2) its accessibility, quantity, thickness, depth, and other conditions that affect the cost of its extraction. It must be considered a workable coal if its value, as determined by its character and heat-giving quality, exceeds the cost of extraction, either as judged by actual experience at the point where it is found or as judged by actual experience on similar coals similarly situated elsewhere. There are no absolute limits to any of the factors. The mining of 1 inch of coal that may involve the mining of 3 feet of rock is physically possible but would not pay. Most unworkable coal beds

lack one or more of three things—quality, thickness, accessibility—that is, they are too poor, too thin, or too deep. Other things—such as poor roof, gas, water, faults, pitch, and lack of timber—may render mining difficult and temporarily unprofitable, but most or all of them are subject to engineering control. They may depreciate the value of the coal and defer its mining but may not make it unworkable.

QUALITY.

Coal is essentially a fuel. The heat afforded by burning coal is derived mainly from its carbon and the hydrogen that is free to burn. Associated with these are oxygen, nitrogen, water, and ash. A pound of the best coal, which contains about 90 per cent of carbon and "available" hydrogen and 10 per cent of the other ingredients, will yield from 14,000 to 15,500 British thermal units. A British thermal unit ("B. t. u.") is the amount of heat required to raise the temperature of 1 pound of water 1° F. under certain standard conditions. Poorer coals contain larger percentages of noncombustible constituents and correspondingly less carbon and available hydrogen, and their heating value (in British thermal units or other units of measurement) is reduced in much the same ratio. On analysis some coals show a content of all impurities that is in excess of the average; others show an excess of ash or water only; but whether the increase is in ash or water, or both, its effect is to decrease the heating value of the coal as expressed in B. t. u. Instead, therefore, of specifying the maximum quantity of ash or water allowable in a commercial or salable coal the regulations fix a minimum value in B. t. u. which will cover either one or any combination of these two or any other impurities. The limit of allowable impurity in a salable coal is affected by the facts that very wet coals may be improved by air drying and that coals which are very high in ash may usually be improved by washing or may, perhaps, be used in a producer-gas plant. The possibility that improvements may be devised in the utilization of coal—such as its entire utilization at the mine for producing electric power—makes the determination of the lowest limit of usable quality of coal difficult and very uncertain. Again, in a study of the B. t. u. value of low-grade coals that are now worked, difficulty is encountered in the fact that many of the earlier samples taken were weathered coal. On account of the possible improvement of the quality of the coal by drying or by washing, the lowest limit of usable quality is fixed by analysis of an air-dried sample, and if the coal as obtained in the mine contains a very high percentage of ash the possibility of its being washed is considered. Analyses of many samples cut in the mine from unweathered coal, according to the practice of the Geological Survey and the Bureau of Mines, indicate that any coal mined

commercially in the United States to-day will yield, after being washed or air dried, at least 8,000 B. t. u. This figure has therefore been fixed as the minimum B. t. u. value of any coal that shall be considered workable. In practice the washed product of any coal subject to washing must have at least 50 per cent of the weight of the unwashed coal. The washability of any coal is determined on a sample of one-quarter inch size by a float and sink test, the liquid used having a specific gravity of 1.5. Even if its workability is thus indicated in the laboratory it can not be considered workable unless there is sufficient water in the field for washing it.

THICKNESS.

More coal is unworkable because it is too thin than for any other reason. The result of a study of the relative cost of mining in relation to the thickness of beds is given on pages 83-86.

For the purpose of classification a careful study was made of the thicknesses of coals that are actually mined in a large commercial way. Many of the facts disclosed by this study have been published.¹ By platting these with reference to the B. t. u. content of the coal it became evident that in actual practice coals yielding 10,000 B. t. u. are worked with profit down to a thickness of 18 or 19 inches, that coals yielding 12,000 B. t. u. are worked down to 14 or 15 inches, and that better coals are mined from beds still thinner. Some coals of the qualities mentioned are mined from beds that are thinner than those noted above, but under very exceptional conditions. In considering the low-grade coals three special factors must be noted: (1) Most of them occur in rocks of more recent age than the others, which have been less affected by mountain-making forces and are therefore less indurated. On this account it is thought that future extensive mining may show the frequent necessity of leaving some of the coal for roof and of leaving larger pillars. (2) Owing to the air-drying loss in very wet coals they are likely to shrink considerably before they are marketed. (3) If the low B. t. u. value of these coals is due to their high content of ash an allowance should be made for loss in washing. For these reasons the minimum thickness for beds of the low-grade coals is set much higher in proportion to B. t. u. value than for beds of coals of higher grade.

The minimum minable thickness of bed is fixed at 14 inches for all coals having more than 12,000 B. t. u. For coals having less than 12,000 B. t. u. the minimum minable thickness increases at the rate of one-tenth inch for each decrease of 100 B. t. u. down to 11,000, then at the rate of one-tenth inch for each 50 B. t. u. down to 10,500, then at the rate of one-tenth inch for each 25 B. t. u. from 10,500

¹ Fisher, C. A., Depth and minimum thickness of coal beds as limiting factors in valuation of coal lands: Bull. U. S. Geol. Survey No. 424, 1910, pp. 56-62.

down to 10,000. The increase for coals yielding less than 10,000 B t. u. is at the rate of one-tenth inch for each decrease of 10 B. t. u. in the coal. The following table gives the thicknesses for B. t. u. of even five hundreds:

Minimum thicknesses for even five hundreds B. t. u.

B. t. u.	Inches.	B. t. u.	Inches.	B. t. u.	Inches.
15,000	14	12,500	14	10,000	18
14,500	14	12,000	14	9,500	23
14,000	14	11,500	14½	9,000	28
13,500	14	11,000	15	8,500	33
13,000	14	10,500	16	8,000	38

An important question that frequently arises is, What value, in relation to thickness, shall be given to split or broken beds? The general practice of the United States Geological Survey in classifying coals has been to give a split bed the value of an unbroken bed with which it can fairly be compared. It is evident that a solid 3-foot bed is worth more than two 18-inch benches separated by 6 inches of clay or shale. After careful study the Survey adopted the simple expedient of prescribing that any parting or bench of bone or impure coal included in a bed injured the value of the coal of the bed in amount equal to the thickness of the parting. Thus the split bed just cited, with its 6-inch parting, is regarded as equivalent to a solid bed 30 inches thick (36 inches of coal minus 6 inches of parting equals 30 inches). If the benches on either side of the parting are not of the same thickness the thickness of the parting is deducted from the thickness of the thinner bench. It is not necessary to consider the whole thickness of a coal bed. It is the practice of the Survey to start with the best bench, if in itself not of workable thickness, and to add the thickness of the next bench above or below after deducting the thickness of the intermediate parting. If the whole bed thus included is still not of workable thickness and more benches exist above or below, the thickness of these benches is added, after subtracting the thickness of the parting between them and the principal bench. If a parting is thicker than the thinner adjoining coal bench, that bench is considered as having no value. This practice is best illustrated by a group of concrete examples. (See fig. 2.)

As a matter of practice two coal layers, each workable, are treated as parts of a single bed if the two layers both exceed in thickness the parting between them and the parting does not exceed 3½ feet. In general two layers of coal are treated as two beds if the parting between them exceeds either one in thickness, and their workability is determined on that basis.

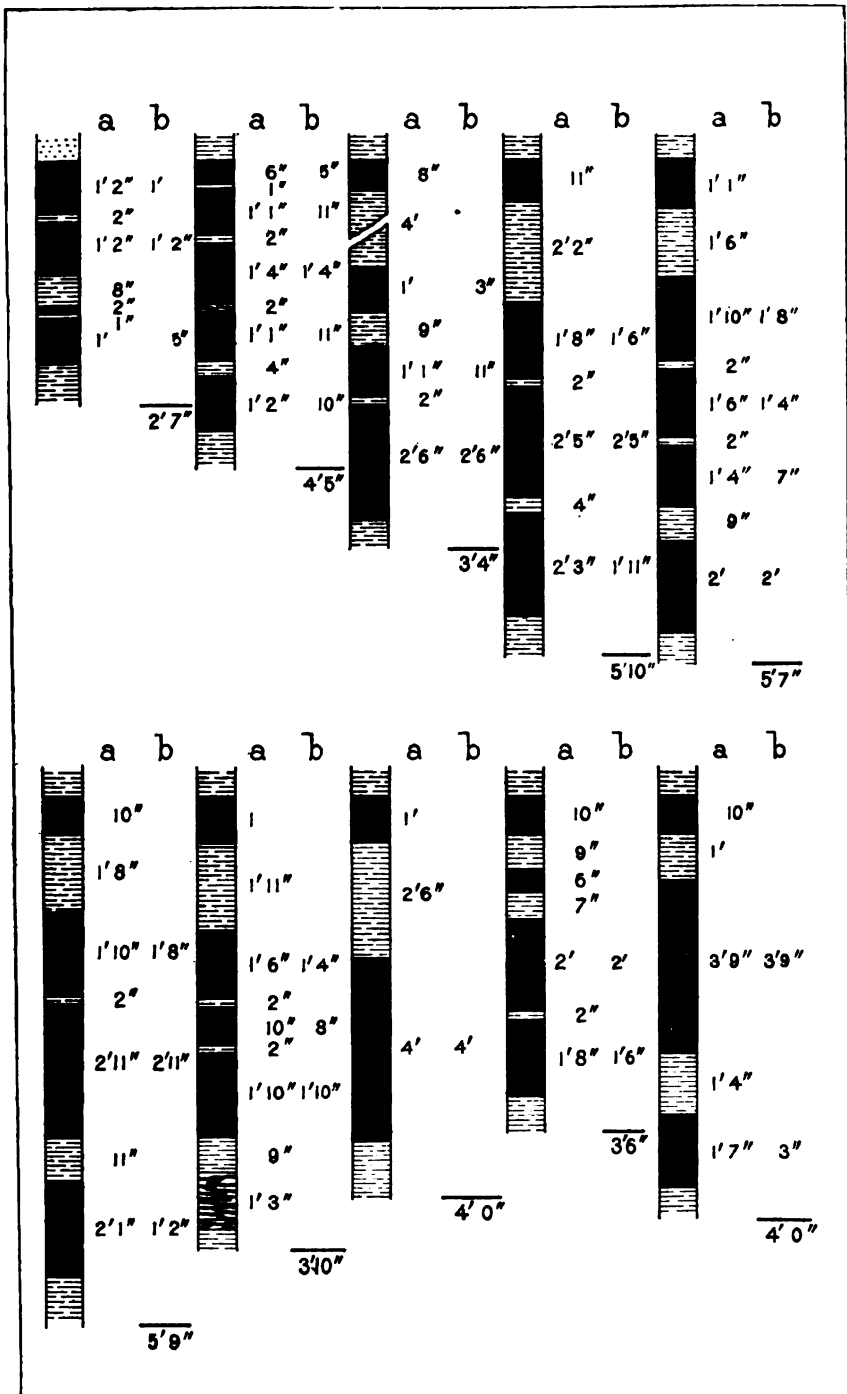


FIGURE 2.—Diagram showing split or broken beds and their value for classification: a, measured thickness; b, equivalent thickness used in classification and valuation.

The criteria given in the preceding paragraphs are intended to determine the workability or nonworkability of a coal measured at any given point. The most difficult problem in classification is the determination of the probable limits of workability of an irregular coal. Coal occurs in beds ranging in thickness from a fraction of an inch to 100 feet or more and in areal extent from a few square feet to thousands of square miles. Some beds maintain a nearly uniform thickness over hundreds of square miles. Others may be traced at the same geologic horizon over hundreds or thousands of square miles but vary greatly in thickness, ranging from a few inches to several feet or back again within a quarter of a mile. Every grade of regularity or irregularity between these extremes is found, and it is possible to determine the "habit" of some beds as regards regularity.

The simplest problem is that in which two unequal measurements on a single bed, taken at different places, are available. All such beds are assumed to grade uniformly in thickness from the thicker measurement to or through the thinner measurement, and a limit to the workable coal is thus fixed that, while it may or may not agree with the unknown facts, is the most probable limit. In general, a coal bed that can be traced continuously along the face of a cliff, as can many beds in the West, has usually been assumed to extend under the land back from the cliff at least one-half the length of the cliff outcrop, the lens or bed having the shape of a half-circle, the length of the cliff outcrop being the diameter of the circle. Obviously, if the outcrop runs along the cliff for many miles, the extension of the coal back from the outcrop may be modified by many other factors, such as limit of depth, or outcrop on the opposite side of the hill. If the bed outcrops along the cliff with irregular thickness, only a moderate extension of the bed behind the cliff is assumed, the estimate being based on the character of the irregularities shown by measurements made along the cliff, or by a general knowledge of the extent of the lenses of that particular coal or of coals of that group, and depending on the general "habit" of the bed, if known, and also taking into account all local features. If the exposed outcrop does not extend in a straight line, but, as is more common, runs in and out of ravines, careful note is made of the thickening or thinning of the coal between one point of measurement and another in order to detect, if possible, any general tendency of the bed to thicken or thin in any direction, and all these measurements and tendencies are taken into account in determining the probable extent of the lens in any direction.

Many beds studied are known to be of less than workable thickness in larger or smaller part, and any measurement showing a workable thickness on such a bed must usually be considered as a measure taken at the center of a small lens of workable coal. A discovery

or measurement of a coal bed by a well, or by drilling, will have the same value as an isolated measurement on the outcrop. The content and shape to be assigned to any lens must depend on conditions and are largely matters of judgment, and such assignments or determinations especially require a wide knowledge of coals and of the particular group of coals to which the bed under consideration may belong. To insure uniformity in treating the thousands of questions of this kind that may arise—for nearly every field involves some, and many fields involve a great number—the Geological Survey has gradually established a series of precedents, and in every question the attempt is made to reach conclusions by means of mathematical calculation. The limits of this bulletin will not allow the consideration of these methods here.

DEPTH.

Some of the facts about the deep mining of coal in this country and abroad have been presented and discussed in an earlier bulletin of the Survey.¹ Not many years ago it was the common opinion and practice in parts of the West to consider as coal land only land on which coal actually cropped out, and requests are still occasionally sent to the Geological Survey asking the reclassification of certain land that had been previously classified as coal land, the writers contending, and supporting their contention by abundant affidavits, that the land is noncoal, because no coal shows at the surface and none has been found on it in wells. If such land should be considered noncoal land, however, most of the coal now mined in Illinois, Indiana, western Kentucky, Michigan, Kansas, and some other States comes from noncoal land, for most of the mines in those States are on lands where the coal mined does not crop out but is reached by shafts. The actual outcrop of most of the coal mined in these States is from 5 to 75 miles away from the shafts.

Two questions are here involved: (1) How deep can coal be mined? (2) Can all coals be mined to the same depth? Coal is now being mined to a depth of practically 4,000 feet (3,937 feet), and many shafts in England, Belgium, France, and Germany go deeper than 3,000 feet. Moreover, a consideration of the still greater depths to which substances other than coal are being successfully mined and a study of the deepest coal mines have convinced many of the best engineers of England and Europe that coal mining will be extended to 5,000 feet.² The fact also that some of the largest coal companies of this country have purchased as coal land certain tracts under which the coal is believed to lie at depths of 5,000 to 6,000 feet

¹ Fisher, C. A., Depth and minimum thickness of beds as limiting factors in valuation of coal lands: Bull. U. S. Geol. Survey No. 424, 1910, pp. 48 et seq.

² *Idem*, p. 51.

shows that some American engineers believe that coal mining will be carried to those depths.

Although, without regard to profit, there may be a physical limit to the depth at which coal can ultimately be mined, in general the depth of mining must be determined by its cost. Given a steady market the depth to which coal can be mined is a question that involves diminishing profits; every added foot of depth adds to the time required to lift the coal, thus reducing the possible output of the mine, to the cost of the lift, to the initial capital required and the interest on that capital, to the size of pillars, and to other factors. Where coal is mined at a certain depth with a narrow margin of profit, obviously mining at a much greater depth will extinguish that margin and render that coal unworkable until markets are better. Of two coals at the same depth, of the same thickness, and in other ways equal but of different quality, one, the better coal, may yield a profit and the other may not. A similar inequality of profit may exist between two coals of the same quality but of different thickness. The thicker coal, which can be mined at a less cost, may be minable at a profit, while the thinner may not. In brief, the depth to which any coal can be worked depends, on the one hand, on its quality, which determines the profits where the cost of working is the same, and, on the other hand, on the cost of mining, which, omitting differences due to depth, is in general proportional to the thickness of the coal. Therefore, given a certain grade of coal which sells on the market at a certain price the profit will be in inverse ratio to the cost of mining, and hence, other things being equal, the depth to which that coal can be mined will differ for different thicknesses of coal and is assumed to vary in direct proportion to the value of the coal as computed from the cost of mining.

The depth to which any coal can be mined is therefore assumed to be directly proportional to the B. t. u. value of the coal and inversely proportional to the cost of mining for different thicknesses. Thus below the adopted minimum depth of 500 feet, a 10,000 B. t. u. coal can be mined to only two-thirds the depth of a 15,000 B. t. u. coal, and an 8,000 B. t. u. coal to two-thirds the depth of a 12,000 B. t. u. coal of the same thickness. If 5,000 feet is assumed as the maximum possible depth at which any coal can be mined, it is also assumed to apply only to coal of the highest grade and to the thickness costing the least to mine—in other words, to a 15,000 B. t. u. coal 6 feet or more thick. By this assumption a 6-foot coal of 12,000 B. t. u. is considered as workable to only 4,000 feet or a 6-foot coal of 10,000 B. t. u. to only 3,333 feet.

Elsewhere in this bulletin it is pointed out that the cost of mining a ton of coal is much higher for thin beds than for thick beds. There is no great difference in the cost of mining coals between 6 and 10

feet thick, but, especially in the West, the cost of mining coals less than 6 feet thick increases as the thickness decreases. It has therefore been assumed that a coal of the minimum thickness for its grade is workable to a depth of not more than 500 feet; that a coal 6 feet or more thick is workable to a depth of 100 feet for each 300 B. t. u. it contains; and that a coal between its minimum thickness and 6 feet is workable to a depth between 500 feet and the maximum depth limit for that coal proportional to the thickness above the minimum. Thus, a 12,000 B. t. u. coal 6 feet or more thick has a maximum depth limit of 4,000 feet and an assumed minimum thickness of 14 inches; a bed of 12,000 B. t. u. coal 4 feet thick is workable to a depth determined by the rule above given as follows: $72-14:48-14::4,000-500:x$; $x=2,050$, which added to 500, the depth limit for a bed of the minimum thickness, gives 2,550 as the depth limit for the bed under consideration.

The accompanying chart (fig. 3) is copied from part of a large-scale diagram used by the Geological Survey in classifying coal land. It is arranged to show the depth limit fixed for a coal of any B. t. u. value of any thickness under 6 feet.

For convenience the readings for the even feet and for the even thousand B. t. u. are given in the following table:

Limits of minable depth of coal of various thicknesses and various heating values in B. t. u.

British thermal units.....	15,000	14,000	13,000	12,000	11,000	10,000	9,000	8,000
Thickness, in feet:								
14.....	811	787	764	751	665	500	.....	.....
2.....	1,275	1,217	1,160	1,100	1,000	825	.....	.....
3.....	2,200	2,075	1,950	1,830	1,665	1,440	950	.....
4.....	3,140	2,940	2,740	2,550	2,340	2,075	1,650	1,440
5.....	4,070	3,800	3,540	3,270	3,000	2,700	2,330	1,920
6.....	5,000	4,666	4,330	4,000	3,660	3,330	3,000	2,660

In general the limit of depth at which a coal bed may be profitably mined depends entirely upon the thickness of the bed and the quality of the coal. If, however, a thin but workable bed that lies below its ordinary minable depth is overlain by a thicker bed that lies within its own minable depth, the lower thin bed may, perhaps, be profitably worked by extending downward the shaft sunk to the higher, thicker coal, whereas the thinner bed could not have been profitably mined alone. A single shaft may also give access to all the coals of a group, and, though the cost of raising all the coal will be the same as if the coal were taken from a single bed, the cost of the shaft and the interest on that cost will be borne by the proceeds of a larger product. In some places the whole cost of a shaft may be borne by the coal of a thick bed that underlies several thinner beds

or that lies in the middle of a group of thinner beds. It is clear that no two shafts that penetrate groups of coal beds will present

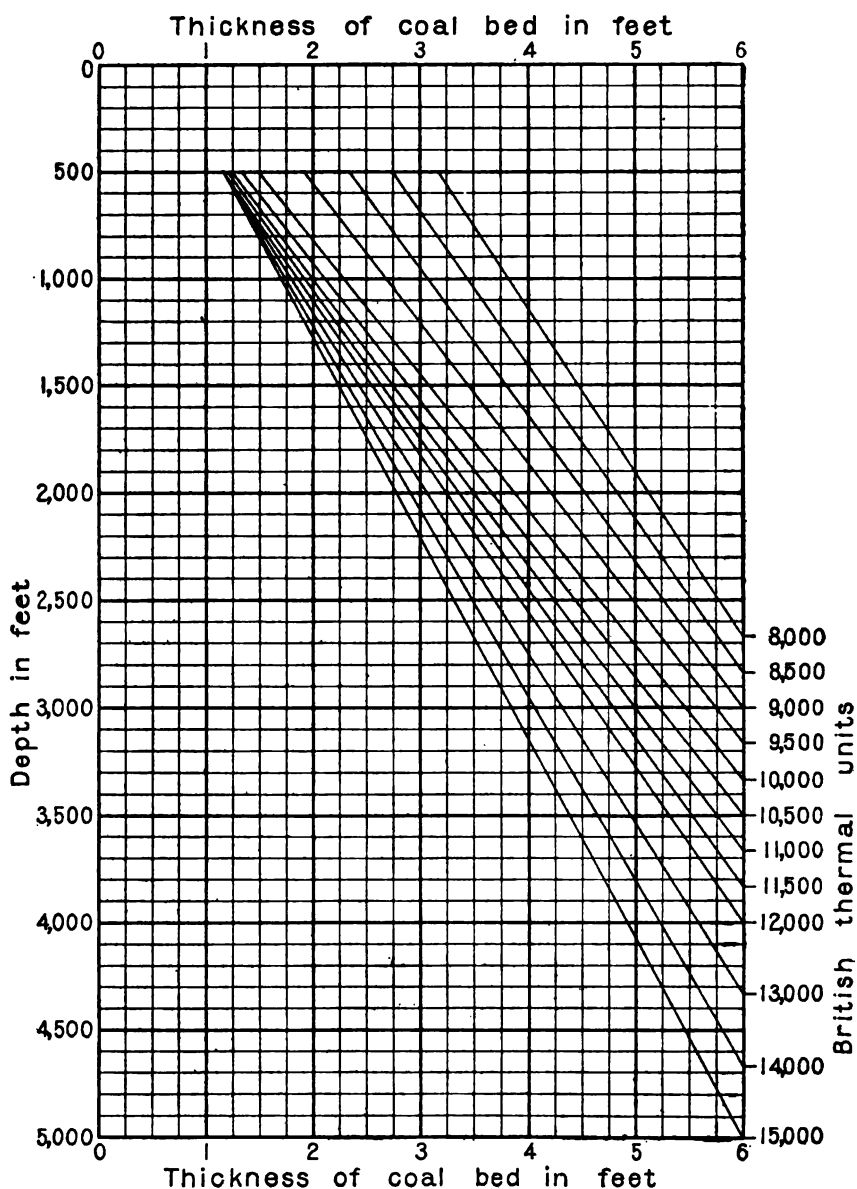


FIGURE 3.—Diagram showing depth limits of coals of different B. t. u. and of different thicknesses under 6 feet.

similar conditions. The coals of such groups will vary in number from two to twenty or more and may be included in an interval

of 50 to 500 feet or more. Every case involving such conditions must be considered on its merits, and here again the Geological Survey has found it necessary to establish a series of general precedents in order to make its treatment of such cases reasonably uniform. In some places it has been found possible to treat a group of coal beds as if they were all gathered at a "center of weight"—that is, at a point determined by multiplying the computed thickness of each bed by its depth from the surface and dividing the sum of the products by the sum of the compensated thicknesses, the thicknesses of the various beds being reduced for partings in the manner already described.

The determination of the limit in depth at which a coal bed can be mined may be complicated by the fact that in a region of very rugged topography the coal gets below minable limit in passing under some high ridge or peak but is within the minable limit under a valley on the other side. Again, in some places the coal outcrops near the foot of a great cliff, such as commonly flanks a high plateau in the West, and it goes below minable depth within a short distance from its outcrop. In order to cover all the different occurrences of this kind the regulations provide that tracts underlain by horizontal beds of coal that lie at depths below the minable limit may under certain conditions be classified as coal land. Horizontal beds of coal may be mined to a distance back from their outcrop equal to 10 times the depth limit for coal of that particular grade and thickness. It is evident that, to be commercially minable at a certain depth, a coal bed must be minable for a reasonable distance from the foot of a shaft sunk to it, in order to pay the cost of the shaft. It is also evident that if it is profitable to sink a shaft to the depth limit for a given coal and then mine out horizontally by drift a certain distance from the foot of the shaft, it would be profitable to mine farther from the foot of the shaft if it were not so deep. The relative values involved in shaft and drift can be easily calculated if unit values are fixed for the horizontal and vertical components. For purposes of classification and valuation it has been assumed that 1 foot of vertical shaft in rock involves as much expense in its construction and maintenance and in the removal of the coal as 7.5 feet of horizontal drift in coal. For this reason the horizontal distance to which the drift can be carried will be no more than the prescribed limit for mining from the outcrop (in this case set at 10 times the vertical limit) minus 7.5 times the depth of the shaft. Thus if the minable depth of a certain coal bed is 2,000 feet, but that bed is horizontal and crops out in a cliff, the area underlain by it is classified as coal land for a distance of 10 times 2,000, or 20,000 feet, back from the outcrop. If the bed is horizontal but lies at a depth of 700 feet, it is assumed that the coal can be mined back 20,000 minus $(700 \times 7.5) = 14,750$ feet from the

foot of a shaft of that depth, even if, away from the foot of the shaft, the coal is more than 2,000 feet below the surface. If the shaft is 1,200 feet deep the coal can be mined back 20,000 minus $(1,200 \times 7.5) = 11,000$ feet. If the coal is at the depth limit at the foot of the shaft it can be mined back 20,000 minus $(2,000 \times 7.5) = 5,000$ feet, or approximately 1 mile in any direction.

CLASSIFICATION BY 40-ACRE TRACTS OR LOTS.

In ordinary practice coal land is disposed of by parcels composed of "smallest legal subdivisions," which are ordinarily quarter-quarter sections, or 40 acres, except along the north and west sides of townships and in areas bordering meandered rivers or lakes, where the tracts are usually irregular in size and shape and are called lots.

The price of a tract that is wholly underlain by coal is the price per acre multiplied by the number of acres. The price of a tract that is only in part underlain by coal is the price of the coal per acre multiplied by the number of acres it underlies. To obtain the sale price per acre of the 40-acre tract or lot, the amount obtained by the above computation is divided by 40 or by a figure representing the actual acreage, but no land must be appraised at a price below the minimum fixed by law. Thus if 24 acres of a 40-acre tract is underlain by coal valued at \$50 an acre the price of the "forty" is 24 times $\$50 = \$1,200$, or \$30 an acre $(\$1,200 \div 40 = \$30)$. The value of the coal in some lands, however, is so small that to charge even the minimum price for them would make the price of the coal abnormally high. For example, to take an actual case: Five acres of a 40-acre tract is underlain by coal 2 feet thick, the total value of which under the regulations is about \$100. The tract is within 15 miles of a railroad, and therefore if it is all sold as coal land it must be sold at the rate of \$20 an acre—that is, the whole tract must be sold for \$800. The coal land in the forty is therefore segregated from the agricultural land, the line of division following the 10 or $2\frac{1}{2}$ acre subdivision. The two portions of the forty thus segregated are treated as separate lots. The 5 acres of coal land is sold for \$100, its value, and the noncoal tract is subject to disposal as nonmineral land. Such a division of the forty into two lots, one coal and the other noncoal, is made only along the outcrop of the coal and only within so short a distance from known corners that little doubt can arise as to the exact position of the outcrop.

OUTCROP COAL AND BURNED COAL.

In coal-mining practice it has been found that the coal along the outcrop and for a distance back of it ranging from 30 to 100 feet or more, the distance depending on the amount of cover, is more or less influenced by weathering, which materially decreases its value. Diffi-

culty due to the thin and weak roof is also encountered in mining on the outcrop. If only a thin edge or corner of coal extends into a forty it may be neglected, as it will give the tract no value as coal land. If the coal outcrops in bluffs or steep hillsides or has a high dip weathering may be neglected. If the coal outcrops at the top of a mesa or on the face of a long, gentle slope an allowance is made for thinness of cover. The possibility of mining outcrop coal by stripping with steam shovel or otherwise is generally considered, as such a method of coal mining has in many places proved highly successful.

In many areas of the West the coal beds have been burned along the outcrop. In some places one or more or all of the beds have been burned not only along an outcrop over a whole field but under the flat tops of mesas where the coal is close to the surface. In a few places mining has shown that this burning extends back 1,000 feet or more and lies many hundred feet under cover. In general, however, the coal does not appear to have burned back more than a few rods. All places where coal has been burned are indicated on the field maps. In classifying the land in these places the edge of the coal is fixed along a line drawn back of the outcrop, only slightly back of it where the line crosses ravines, but to a considerable distance back of it where it crosses projecting divides, especially if the coal is under light cover.

METHODS OF VALUATION.¹

COST OF COAL IN THE GROUND.

The total cost of coal in the ground consists of the original purchase price, interest on investment, amortization charges, taxes, and, if the coal is leased, the cost of inspection and of collecting royalties. The following table shows the amortization and ultimate cost of coal in the ground per dollar of investment for periods ranging from 20 to 40 years, at 5 and 6 per cent interest.

Ultimate cost of coal per dollar of purchase price.

Amortization period in years.	Rate of interest.	Annual interest.	Annual taxes at 1 per cent.	Annual amortization charge.	Total annual cost.	Total cost per dollar of purchase price at end of amortization period.
	<i>Per cent.</i>					
20.....	5	\$0.05	\$0.01	\$0.03	\$0.09	\$1.80
	6	.06	.01	.027	.097	1.94
30.....	5	.05	.01	.015	.075	2.25
	6	.06	.01	.0125	.0825	2.475
40.....	5	.05	.01	.008	.068	2.88
	6	.06	.01	.006	.076	3.04

¹ For a more detailed account of the principles of valuation of public coal land see Survey Bulletin 424, on the valuation of public coal lands.

It is generally agreed that the price paid for coal in the ground should be recovered by the investor during the early years of the mining, when the cost is lowest. Otherwise it must be recovered when the inevitable increase in the cost of working the mine has reduced the profits and the business has reached a condition that is the bane of the eastern coal-mining industry to-day. The initial investment should invariably be refunded within the first 20 years of the life of the mine. The above table shows that if the mine is opened and operated immediately and continuously after purchase the total cost of the coal in the ground will be about two dollars for each dollar of the purchase price. The value of coal in the ground at the time of its extraction is measured by the current royalty rate in the region where the coal is situated. Its value at the time the mine is opened is, then, approximately one-half the royalty rate, as has been indicated. Were it possible to know in advance the exact number of tons that would be recovered from any acre of land, the value of that acre at the beginning of mining would be one-half the royalty rate per ton multiplied by the tonnage recovered. If the royalty rate is 10 cents a ton, the value of coal per ton in the ground when a mine is opened is at least 5 cents. To insure profit and safety, however, the purchaser of coal land, as a rule, in buying demands a margin on the estimated tonnage value (1) as a consideration for the risk of the investment, (2) to offset possible delays in the mining of the coal, and (3) as a contingent against an overestimate of the recoverable tonnage. If this margin is fixed at one-half the estimated value, the coal should have a sale value of $2\frac{1}{2}$ cents a ton if the royalty is 10 cents a ton. Royalties on bituminous coals in the United States range from about 3 to the equivalent of 35 cents a ton. A comparison of royalties paid in the United States, some of which are given in Survey Bulletin 424 (p. 10) shows that 10 cents a ton is not far from the average royalty paid under private leases—somewhat less in the East, somewhat more in the West. Therefore $2\frac{1}{2}$ cents a ton is a fair sale price for unmined coal that is to be mined immediately, where 10 cents a ton is the prevailing royalty. As a matter of fact, where the character and tonnage of the coal are well known to both buyer and seller prices often range from one-quarter the royalty rate almost or quite to the royalty rate. For example, the Pittsburgh coal, in southwestern Pennsylvania, is worked to a thickness of about 7 feet. On an estimate of 1,200 tons recovery per acre-foot this bed should yield 8,400 tons an acre; yet it is reported that 99 separate transfers were made in Westmoreland County between 1901 and 1910 at an average price of \$1,102.70 an acre—over 13 cents a ton—and many of these sales were made at a price much higher than this average. Occasionally the sale price for small tracts adjacent to operating mines may reach the royalty rate.

The general impression that coal lands are sold at low prices is due largely to the fact that in the past most of the sellers had bought their land as farm land, knowing little or nothing of its coal content or value, and had regarded the coal as a little overmeasure on the part of nature for which they were willing to take anything that was offered or that looked good to them. As a result a large number of the recorded sales of coal land have been made at prices that have had little relation to the value of the coal, and in the past a large percentage of the total acreage has been sold at such prices. A recent review of coal-land sales for one year, as recorded in one of the most reliable of the coal journals, excluding all sales of tracts containing over 10,000 acres, which were obviously bought for holding or speculation, showed 40 sales, representing a total of 95,218 acres, at an average price of \$209 per acre. This average price for a year's sales shows the great extent to which coal lands have passed out of their original farmer ownership. Grouped according to prices, it is found that that year's sales as thus recorded ran as follows:

Prices of coal lands sold in one year.

Price per acre.	Sales.	Acres.
\$800 or more.....	3	10,198
\$600 to \$800.....	2	1,633
\$400 to \$600.....	3	417
\$200 to \$400.....	8	14,046
\$100 to \$200.....	10	26,097
Less than \$100.....	14	32,817

In other words, 65 per cent of the sales and the acreage were at \$100 an acre or more and 40 per cent of the sales were at \$200 an acre or more.

It is evident that a large share of these were sales of lands not purchased for immediate development. Sixteen of these sales, conveying 74,633 acres, covered tracts containing more than 1,500 acres, an area generally admitted to be as large as can be economically mined from one plant in present-day practice.

In order to give the prospective buyer an ample margin of safety, the basing prices of the Government coal lands are fixed at only 40 per cent of the value ($2\frac{1}{2}$ cents per ton) named in a preceding paragraph, or at 1 cent per ton for a coal of good average quality—say 12,500 B. t. u.—equivalent to one-tenth of a cent for each 1,250 B. t. u. of the coal. This price is one-tenth the assumed average royalty rate.

FACTORS INVOLVED.

The valuation indicated, however—1 cent per ton for coal in the ground—is not put on all coals indiscriminately. Though the value of any coal is most readily obtained by taking the royalty rate,

the royalty rate itself is based on the average difference between the cost price of the coal ready for sale and the sale price—that is, on the profit. If competition is keen and the profit is low, these facts are reflected in a low royalty rate. Whatever affects the profits affects the royalty rate and correspondingly the value. Other things being equal, the lower the grade of coal the less readily it sells and the less the profit, the royalty, and the value. On the other hand, the more expensive the coal is to mine the less the profit, the royalty, and the value. The Government valuations can not take account of changes in competition, markets, transportation facilities, or freight rates, or other factors that affect the profit, but it can and does take account of the quality and character of the coal, both chemically and physically, which affect the sale price and so the profit and value, and of those natural factors that affect the mining cost. The most important of these factors are thickness and accessibility.

EFFECT OF QUALITY ON PRICE.

One cent per ton is therefore the price put on a good average coal—a noncoking bituminous coal of 12,500 B. t. u. heat value, 6 to 10 feet thick, and at the surface. For coals of other B. t. u. value the same rate of one-tenth cent for each 1,250 B. t. u. is applied, and provision is made for increasing this value (not to exceed 100 per cent) for coking coal or coal that has special qualities which enhance its value in the market, the percentage of increase depending on the quality of the coke it yields or the extent to which its special qualities enhance its value; and on the other hand provision is made for reducing the appraised value because of special impurities, such as sulphur, or because of physical defects that obviously detract from the market value.

EFFECT OF MINING COST ON PRICE.

The cost of mining coal is affected by many factors—such as cost of prospecting, shaft sinking, or other mine opening, surface and underground plant, perhaps community plant, water, supplies, timber, feed, and insurance—all of which vary from place to place or in accordance with the method of working the mine. Within the mine the main factors are mining rate, thickness, depth, and dip or pitch of bed, variations or irregularity in thickness, partings, “sulphur” or other impurities that must be removed, kind of roof or floor, presence of gas or water, provision for drainage and ventilation, haulage and hoisting, faults, and igneous intrusions. Many of these factors give rise to problems for the engineer; others definitely affect the value of the land for coal mining. One of the factors of the latter class—thickness—has so definite and constant a relation to the cost of mining that it must be taken into account in determining the value of all coal land.

VALUE OF THIN COALS.

The cost of mining thin coals increases rapidly with the decrease in their thickness, for the following reasons: The rate paid for mining the coal increases with the thinning of the bed, as do the amount of dead work per unit of output, the cost of trackage, ties, rails, haulage, and ventilation, and, for the very thin coals, the cost of taking up floor or brushing down roof to obtain height.

H. M. Chance¹ has prepared curves expressing the relations between mining cost and thickness for anthracite coal. The figures showing Chance's determinations are given in column 2 of the table on page 84. Similar figures (column 3) were obtained by the Survey for bituminous coals. Detailed cost sheets of mines working coals of different thicknesses were taken and the costs were separated into four items—(a) capital cost (interest, etc.); (b) mining rate; (c) tonnage cost (proportional to output, tippie, office, etc.); (d) acreage cost (proportional to acreage mined out, dead work, hauling, etc.). Obviously, if the recovery per acre-foot is the same, the last item would be double for a 5-foot coal bed what it would be for a 10-foot bed yielding the same output and would be inversely proportional to the thickness of the bed. Though the tonnage recovered is greater per acre-foot from thin than from thick beds, yet the recovery varies so greatly from mine to mine and from time to time that an absolutely invariable recovery from a bed of a given thickness can not be assumed. Therefore, in reaching the results now to be stated, differences in recovery from beds of different thickness have not been considered. As in all studies of coal mining made by the Geological Survey the obtainable figures relating to any particular factor were, if possible, gathered together and platted graphically on a chart, by which it has usually been practicable to show certain definite averages or curves expressing the relation sought. Whenever possible, these curves have been reduced to mathematical formulas. A concrete example is a curve showing the relation between the mining rate and thickness of bed, a relation which it was necessary to determine in working out the total cost of mining beds of different thicknesses. In making this diagram the mining rates at different places in the United States were platted on cross-section paper as shown in figure 4 (p. 85), on which the curve A-B was drawn to express the average relation between these two factors, a relation which was used in later computations.

¹ Chance, H. M., The cost of mining coal: Eng. and Min. Jour., May 29, 1909, pp. 1099-1101.

The following table gives the derivation of the formula showing the relation of the thickness to value of bed, uniform recovery being assumed:

Table showing derivation of formula for relation of thickness to value of bed.

Thick- ness of bed in feet (<i>t</i>).	Average cost.		Ap- proxi- mate combi- nation cost.	Value by in- version.	Differ- ence— 10 minus thick- ness in feet.	Square of amount in col- umn 6.	100 minus amount in col- umn 7.
	Anthra- cite (Chance).	Bitumi- nous.					
1	2	3	4	5	6	7	8
10	1.00	1.00	1.00	1.00	0	0	100
9	1.01	1.03	1.02	.97	1	1	99
8	1.045	1.075	1.05	.95	2	4	98
7	1.10	1.126	1.10	.91	3	9	91
6	1.18	1.20	1.20	.83	4	16	84
5	1.35	1.30	1.33	.75	5	25	75
4	1.65	1.45-1.55	1.50	.66	6	36	64
3	2.13	2.00	2.00	.50	7	49	51
2	3.36	3.00	3.00	.33	8	64	36

The first column in the table gives the thickness of the bed in feet; the second the average cost of mining anthracite at these thicknesses, according to Chance (not including breakage charges); the third column, the computed relative cost for bituminous coal; the fourth column, the approximate combination of the two; the fifth column, the relative values of beds of the same quality of coal of different thickness, obtained by dividing 100 by the cost, given in column 4; the sixth column, the difference in feet between 10 and the particular thickness given; the seventh column, the square of the numbers in column 6; the eighth column, the result of subtracting from 100 the square of the difference between 10 and the thickness in feet. By comparing columns 5 and 8, column 8 is seen to give a close approximation to the computed figures in column 5, and as the figures in column 5 are by no means absolute and fixed the figures in column 8 have been taken as fairly expressing the relative value of different thicknesses of the same coal; but this is found by subtracting from 100 per cent a percentage equal to the square of the difference between 10 and the thickness, or $\frac{100}{100} - \frac{(10-t)^2}{100} = 1 - \left(\frac{10-t}{10}\right)^2$. The value per ton of a bed less than 10 feet thick of a given grade of coal may therefore be found by multiplying the normal value per ton for a 10-foot bed of coal of that grade by $(1 - \left(\frac{10-t}{10}\right)^2)$.

In valuing land by the acre-foot, however, an additional factor must be considered, namely, that a larger recovery of coal per acre-foot is possible from thin beds than from thick beds. This difference offsets in a measure the rapid increase in mining cost with thinning of beds. Thus 1,000 tons an acre-foot for a 10-foot bed and 1,200

tons an acre-foot for a 6-foot bed are considered fair recoveries. But 1,000 tons of coal at 1 cent a ton is \$10, and 1,200 tons at 0.84 cent a ton (84 per cent being the corresponding value of a 6-foot bed) is \$10.08. It is then practically immaterial whether land containing a 6-foot bed is valued at 84 per cent of the normal value of land containing a 10-foot bed of coal of a certain grade and an assumed recovery of 1,200 tons an acre-foot or whether the same value per ton and the same recovery, per acre-foot are assumed as with the 10-foot bed. As the latter treatment is the simpler it has therefore

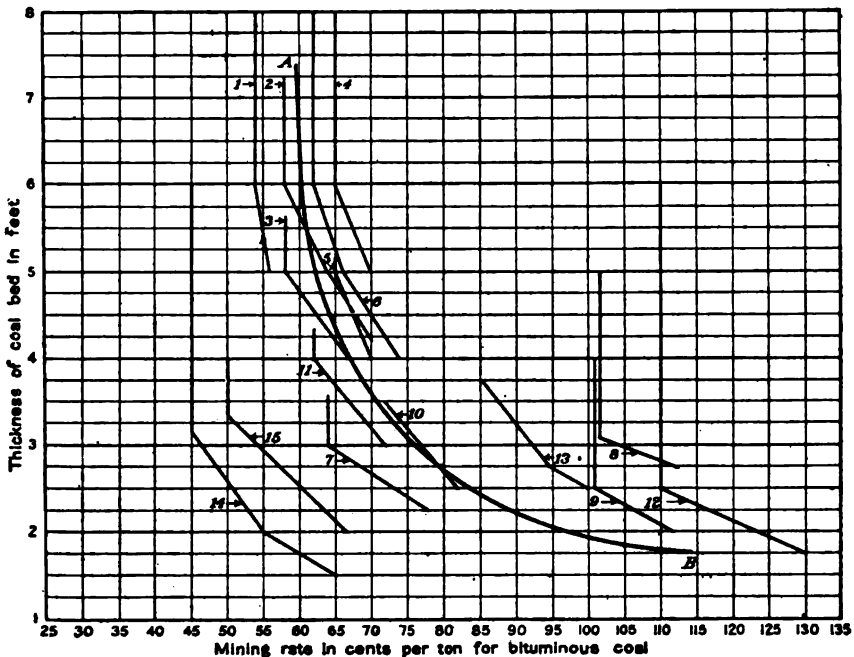


FIGURE 4.—Rates paid in the United States for mining coal of specified thicknesses and curve (A-B) showing average relation between mining rate and thickness. 1, 2, 3, Wyoming, southern fields, run of mine, agreements of 1912. 4, 5, Colorado, north-eastern coal fields, run of mine, agreements of 1912. 6, Montana, Red Lodge field, run of mine. 7, Indiana, miscellaneous agreements, run of mine. 8, Indiana, block coal agreements, screened. 9, Michigan, summary of agreements of 1910. 10, Missouri, summary of agreements, run of mine. 11, Missouri, Bates and Vernon counties, run of mine, agreements of 1908. 12, West Virginia, summary of agreements, screened. 13, Kentucky-Tennessee, Jellico mining district, screened. 14, Tennessee, Durham Coal & Iron Co., run of mine. 15, Tennessee, summary of agreements, run of mine.

been adopted and the value of a ton of any coal in the ground is taken as constant for thicknesses between 6 and 10 feet.

The rate of increase in cost of mining a bed less than 6 feet thick, however, is too great to be compensated for by the greater recovery per acre-foot. After making various assumptions as to fair average acre-foot recovery for thin coals—assumptions based on known recoveries—and after computing the value of the coal in thin beds, accord-

ing to the formula given on page 84, it was decided to avoid a sliding scale both in value and recovery by reducing the value of beds less than 6 feet thick 10 per cent for each foot below 6 until the minimum for that coal is reached. Thus the coal in a 5-foot bed is computed at 90 per cent of the value per ton of the coal in a 6-foot bed, the coal in a 3-foot bed at 70 per cent of the value per ton of the coal in a 6-foot bed, and so on. This reduction for the value of the coal in beds less than 6 feet thick is readily computed by multiplying the normal value per ton by $\frac{4+t}{10}$, where t is the thickness

in feet. Figures showing the results obtained by multiplying the relative value of coal in thin beds, given in column 8 of the preceding table, by various assumed rates of recovery were plotted on cross-section paper and an arbitrary line was drawn through the middle of the group of lines so obtained. This line is practically a straight line, giving a reduction in value of 10 per cent for each 1-foot reduction in thickness, and was accepted as representing fair average relative values.

Sufficient data were not at hand on the relative cost of mining coals more than 10 feet thick to lead to definite figures, or figures having more than approximately authoritative value. It is, however, generally recognized that the cost of working coals does not continue to decrease indefinitely as the beds increase in thickness, for the increased cost of timbering and increases due to other practical difficulties gradually overcome the gain due to smaller acreage, and increases for the thick coals in general probably entirely offset that gain. From beds more than 10 feet thick, other things being equal, the recovery per acre-foot decreases with increase in thickness, owing to the necessity of leaving larger pillars and the difficulty of reaching all the coal. It has therefore been assumed that the recovery diminishes on each additional foot above 10. Thus a 16-foot bed takes first the normal value on 10 feet; next the eleventh foot is valued at only 99 per cent of the value fixed for the tenth foot, the twelfth foot at 98 per cent, and so on, the sixteenth foot having a value of only 94 per cent of the value fixed for the tenth foot.

In computing acre values on beds over 10 feet thick it has been found best to use the normal basing value in cents per ton of a 10-foot bed and assume the same recovery per acre-foot and then compute the thickness (t') of a bed that without deduction will yield the same acreage recovery as the bed in question. Where the thickness in feet (t) is more than 10 the equivalent thickness (t') is expressed by the following formula: $t' = 9 + \frac{t-9}{2} \left(2 - \frac{t-10}{100} \right)$.

Summarizing the above: The Government price per ton for a bed 6 to 10 feet thick will range from 6.4 mills (0.64 cent) for an 8,000 B. t. u. coal to 1.2 cents for a 15,000 B. t. u. coal, but if a coal is of coking quality its price may be increased to a maximum of 2.4 cents, or if its quality is low it may be decreased to one-tenth cent or less.

In computing the thickness of a split or broken bed for valuation the same allowance is made as in considering classification.

The following table gives the computed value per acre of ordinary coal beds of different B. t. u. and different thickness:

Normal price per acre of coal land containing one bed of coal with heat values from 10,000 to 15,000 B. t. u. and thickness from 1 foot 6 inches to 50 feet.

Actual thickness.	Equivalent computed thickness.	Price per acre.						Tons per acre at 1,750 tons per acre-foot.
		10,000 B. t. u.; 0.8 cent per ton.	11,000 B. t. u.; 0.88 cent per ton.	12,000 B. t. u.; 0.96 cent per ton.	13,000 B. t. u.; 1.04 cents per ton.	14,000 B. t. u.; 1.12 cents per ton.	15,000 B. t. u.; 1.20 cents per ton.	
<i>Ft. in.</i>	<i>Ft. in.</i>							
1 6	8	a \$6.60	a \$7.25	a \$7.93	a \$8.58	a \$9.25	a \$9.90	2,625
2	1 2	a \$9.60	a \$10.56	a \$11.52	a \$12.48	a \$13.44	a \$14.40	3,500
3	2 1	a \$16.80	a \$18.50	20.15	21.85	23.50	25.20	5,250
4	3 2	25.60	28.16	30.75	33.30	35.80	38.40	7,000
5	4 6	36.00	39.60	43.20	46.75	50.40	54.00	8,750
6	6	48.00	52.80	57.60	62.40	67.20	72.00	10,500
7	7	56.00	61.60	67.20	72.80	78.40	84.00	12,250
8	8	64.00	70.40	76.80	83.20	89.60	96.00	14,000
9	9	72.00	79.20	86.40	93.60	100.80	108.00	15,750
10	10	80.00	88.00	96.00	104.00	112.00	120.00	17,500
20	19 5	155.60	171.20	186.72	201.94	218.00	233.30	35,000
30	27 10	223.40	245.60	268.00	290.00	312.50	334.80	52,500
40	35 4	282.70	311.00	338.30	367.50	396.00	423.00	70,000
50	46 9	374.80	412.00	449.00	486.50	525.00	562.00	87,500

a Where the computed value is less than \$20 the minimum prescribed by law is placed on the land—\$30 if the lands lie within 15 miles of a railroad and \$10 if more than 15 miles from a railroad.

VALUE OF IRREGULAR BEDS.

If the calculated thickness of any coal bed or group of beds shows a considerable variation in thickness and shows that this variation is not regular, it must be recognized that on any 40 acres concerning which no data are available the coal may be as thick or as thin as the maximum or minimum measured in adjacent areas. Because of the limited acreage that one purchaser may now legally buy and because he may not exchange his land for other land if it proves not to be underlain by as much coal as had been estimated in determining its price, an allowance should in fairness be made to him for possible local thinning.

If any regularity is shown in the changing thickness of the coal, the practice is adopted of drawing lines of equal thickness, a feature

best illustrated by giving a concrete case, such as is represented in figure 5.

On this map lines were drawn from the position of one measurement to the position of each adjacent measurement and the thickness was assumed to grade uniformly from one to each of the other points. Valuation is then based on the average thickness thus found for each forty that is being valued. If the measurements do not show any regularity in the change of thickness, the Survey has adopted a method of computing thickness that permits the thickness of the coal under any tract of land to be considered as less than the average of the measurements, in order to favor the buyer, for the reasons already stated. For while the coal is as likely to be above the average as below and, mathematically, is more likely to be just the average thickness than any other, yet a cautious buyer bargaining for coal would always want to discount the probability a little, as a matter of safety. If all the measurements on a bed indicate the same thickness, that thickness may be safely taken as the thickness of the coal under any land included by the measurements. If the measurements vary but slightly from the average, the thickness under the land where no measurements are obtained is not likely to be much below the average. If, however, the variation is large, the coal in some places may be even thinner than the smallest measurement; yet to assume that the coal under all the land where no actual measurements were made is as thin as the thinnest measurements obtained would be overcautious. A more probable thickness is ob-

tained by multiplying the average of the measurements by $(1 - \frac{SD}{S})$,

in which S is the sum of all the measurements and SD is the sum of the numbers obtained by subtracting from the average each measurement below it or subtracting the average from each measurement above it. For example, if the measurements on a given bed in a certain area are 4 feet, 5 feet, 7 feet, 3 feet, 4 feet, 8 feet, 5 feet, 2 feet, 4 feet, 2 feet, 6 feet, and 10 feet, the average of all the measurements is 5 feet; the sum of the measurements is 60 feet; the difference between the several measurements and the average 5 feet is 1 foot, 0, 2 feet, 2 feet, 1 foot, 3 feet, 0, 3 feet, 1 foot, 3 feet, 1 foot, 5 feet, which added together give 21 feet; so 21 feet divided by 60 has been called the "modulus of irregularity" and has been adopted

as a factor of safety; $1 - \frac{21}{60}$ or 100 per cent - 35 per cent = 65 per

cent; 65 per cent of 5 feet = $3\frac{1}{4}$ feet; therefore $3\frac{1}{4}$ feet is taken as a safe average thickness on which to sell the coal—in other words, the thickness which it is highly probable will be reached or exceeded by the coal under any of the land within the area of the measure-

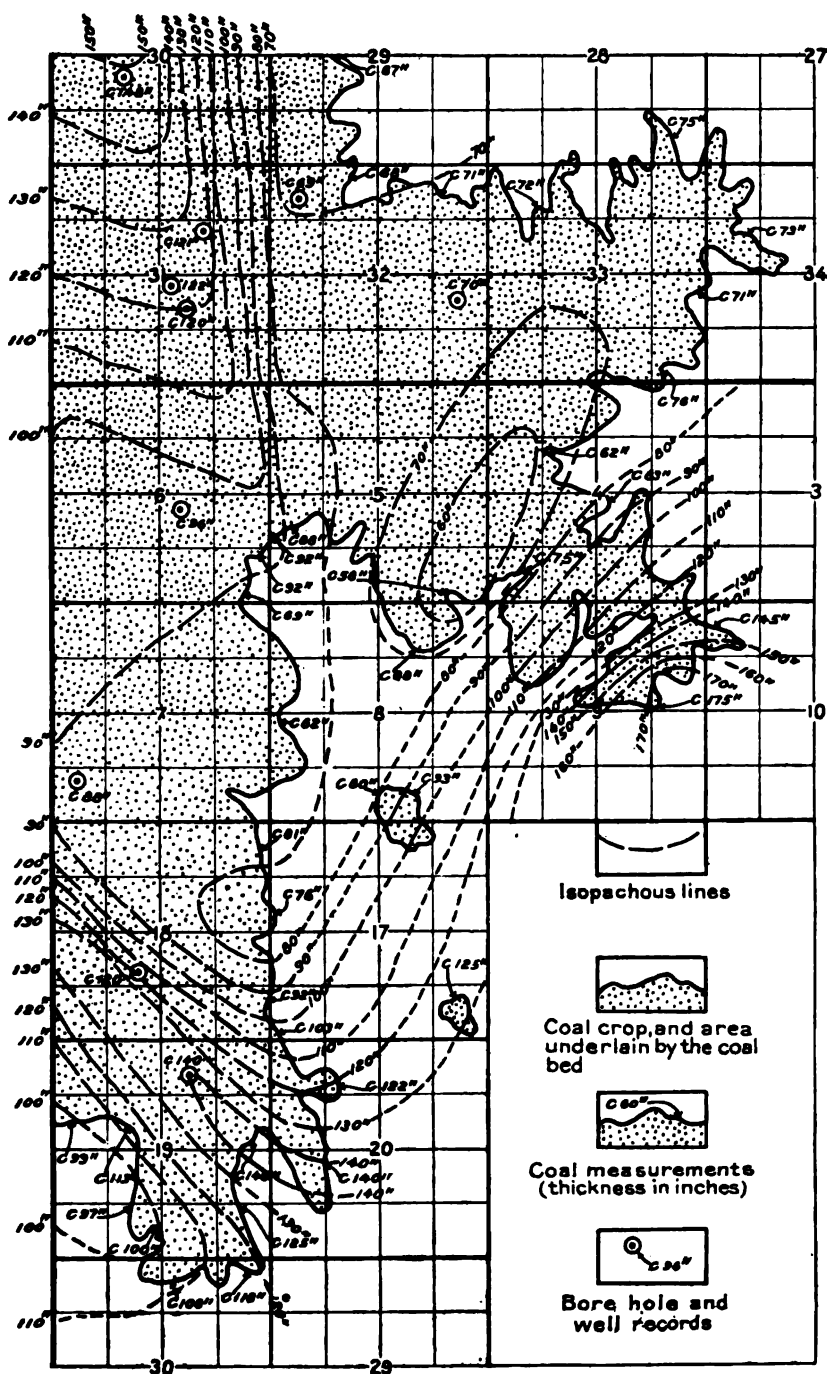


FIGURE 5.—Sketch map showing lines along which a coal bed is of equal thickness (isopachous lines), drawn for use in the valuation of coal land.

ments given. In this, of course, the Government is favoring the buyer to the extent that the computed safe average is below the actual average of measurement; but, on the other hand, it is believed that this is no more than would properly be demanded by the average purchaser of private coal lands who, knowing the measurements of thickness on the land to be purchased, wishes to safeguard himself against the possibility that the measurements will prove to be above the average of all of the coal. This safeguard is, of course, in addition to the allowance for such a possibility in the purchase price.

VALUE PER ACRE

The Government prices for coal land are based on an assumed possible recovery of 1,000 tons per acre-foot. As an acre of coal a foot thick contains 1,750 to 1,800 tons, this recovery represents about 60 per cent of the coal in the ground. This percentage was long used in commercial estimates, though at present it is usually much exceeded by the percentage actually recovered in all good coal mining, especially in the bituminous fields of western Pennsylvania and in many regions in the Central West where the longwall method of mining has been practiced, by which the recovery in many places is estimated at 90 per cent or more.

Although a recovery of 1,000 tons per acre-foot is fixed in the regulations and is used in all computations, the value per ton assumed for coals thinner than 6 feet or thicker than 10 feet recognizes the recovery of more than 1,000 tons per acre-foot for coal in thin beds and of less than 1,000 tons per acre-foot for coal in very thick beds, thus avoiding the use of a variable recovery factor in making individual computations.

If more than one bed underlies a tract of land the early rule in valuing was to take the normal value of the bed likely to be worked first, 60 per cent of the value of the bed next worked, 40 per cent of the value of the next, and 30 per cent of the value of any others, the reduction being made on the beds not worked at first to allow for interest on the investment for the long period during which they remained in the ground. Fuller consideration of this subject, however, and closer study of the operation of many mines that work several beds simultaneously or one immediately after the other and of the practical advantages of using the same plant for working beds either simultaneously or successively have led to the belief that these advantages more than outweigh the added interest that accrues during the longer period of holding.

Accordingly, under the regulations now in force, consideration is had only of the total quantity of coal in the ground, no reduction being made for interest on the investment if, after allowance for

the reduced value of the thin beds, the sum of the thicknesses of the beds does not exceed 10 feet. If the total thickness of the coal under a tract of land, after reduction for thin beds and for partings, is more than 10 feet, the total value of the coal is computed by the formula previously given for computing the value of thick beds.

REDUCTION FOR DEPTH.

It has been pointed out that the determination of the depth to which a coal may be profitably mined is a problem involving the consideration of diminishing profits. If a coal that is being mined near the surface is yielding a net profit of 25 cents a ton and if the cost of mining it increases 1 cent a ton for every 100 feet of increase in depth (purely an assumption), it is evident that the profits will disappear when the mine has reached a depth of 2,500 feet, so that the coal becomes unminable at a reasonable profit at some point of less depth, say 2,000 feet. Obviously anything that increases the profits—such as a gain in quality—will increase the depth of profitable mining, and anything that decreases the profits—such as an increase in the cost of mining—will decrease the depth of profitable mining.

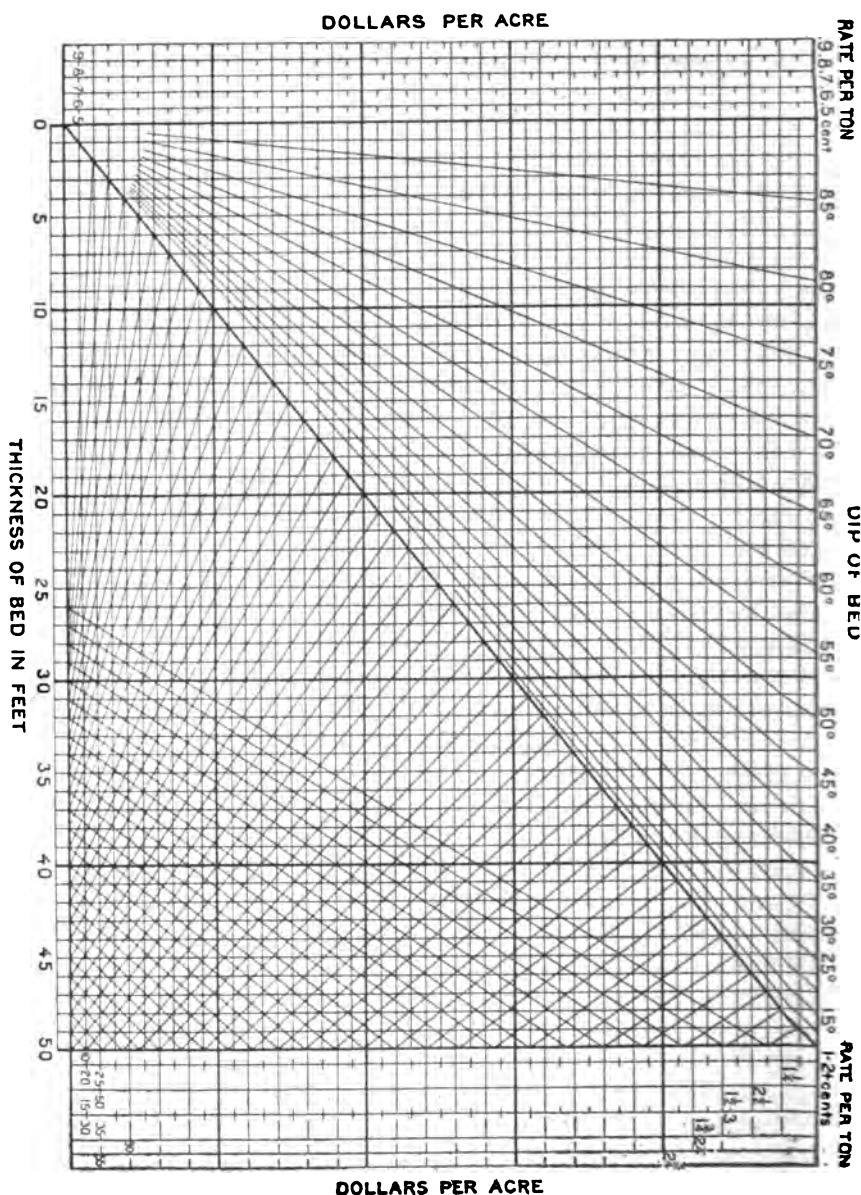
If depth limits are assumed for coals of different grades and different thicknesses, it may also be assumed that the cost of mining increases uniformly with increase of depth, though it is strongly suspected that the cost of mining increases at an accelerating rate as the depth increases, but as sufficient data to prove this are not available a uniform rate of increase has been assumed.

If a certain coal has a normal value at any depth within 500 feet of the surface its value has been assumed to reach zero at its depth limit, and its price has been decreased uniformly from a point where it goes below the 500-foot depth down to its depth limit. If, for example, a bed has a value of \$60 an acre at the depth of 500 feet and its depth limit is 2,500 feet, and if it reaches its depth limit 3 miles beyond the point where it lies at a depth of 500 feet, its dip remaining constant, it loses a value of \$60 in crossing twelve 40-acre tracts, or \$5 for each forty. The successive forties underlain by this coal would therefore be valued at \$55, \$50, \$45, \$40, \$35, \$30, \$25, and thence to the depth limit at \$20.

Ordinarily the depth of a bed does not increase uniformly to its limit, but its steepest pitch or dip is at its outcrop and its dip gradually lessens toward the center of the basin in which it lies. Its depth at all places is indicated on the field sheets by contour lines representing uniform elevations above sea level. From these contour lines it is possible to compute the average depth of the bed under any 40-acre tract, and, the rate of diminishing value having been

established by dividing the difference between the depth limit and 500 feet by the normal value at the surface, each 40 acres can be

FIGURE 6.—Reduced copy of diagram used by the United States Geological Survey in computing value of coal lands; one-fifth size. From tracing that omits much of the detail on the edges of the chart.



valued accordingly. The average depth of coal in a forty that is crossed at an angle by the outcrop or the depth-contour lines is the depth at the geometrical center of the area underlain.

If the dip of the coal bed whose value is given above had not been regular the rate of its diminishing value would have been $\frac{2500-500}{60} = \$1$ for each $33\frac{1}{2}$ feet, so that if the depth under a given forty averaged 1,600 feet, the value of the forty would be

$$\$60 - \frac{1600-500}{33\frac{1}{2}} = \$27.$$

If more than one bed of coal underlies a 40-acre tract and the beds are not close together each one is valued independently and the value of the forty is taken as the sum of the value of the independent beds. If several beds occur in a group a normal value is figured out for the group and this value is reduced according to the depth. In fixing the value of a group of dipping beds allowance is made for the change in the value of the group due to the lower beds passing below the 500-foot line before the higher beds and reaching the depth limit before they do.

Formulas have been worked out to facilitate the calculation of the value of beds involved in some of the more common types of computations. These formulas are platted graphically on large diagrams and the results are read directly from them. These diagrams contain so much matter that a reproduction of one of them (fig. 6) on the reduced scale necessary for publication in this bulletin does little more than give a general idea of their character, particularly as they are too involved to permit their description in a bulletin that is not intended to set forth details of classification.

ALLOWANCE FOR FAULTS.

Faults—that is, breaks in the rocks involving a movement of beds on either side of the break—occurring in a coal field depreciate the value of the coal for mining and in places may render it entirely unworkable. Small faults may be disregarded unless they are so numerous as to render the coal expensive or difficult to mine. If, however, the throw of the fault is large—that is, if the edges of the beds that are broken have been so far separated by movement at an angle to the bedding that entries can not handily be driven from the coal on one side of the fault to the coal on the other—the value of the land is clearly less than that in which there is no fault, its smaller value being due both to the extra cost of recovery and to possible crushing of the coal along the fault planes. The price of coal in such places is determined by considering the two parts of any forty traversed by the fault separately, and giving the normal price to the part having the higher value and 40 to 95 per cent of the normal price to the part having the lower value. From the total thus obtained 5 to 15 per cent may be deducted to allow for crushing along the fault plane.

EFFECT OF INTRUSIONS.

Intrusions of igneous rock may affect a coal bed favorably, as where they occur in sheets close above or below the coal and have had the effect of changing it from a bituminous or lower grade of coal to an anthracite. The physical character and B. t. u. value of such coals reflect amply the favorable results of the intrusion. More often the intruded masses of igneous rock are in the form of more or less vertical dikes that cut the bed in various directions. Obviously these dikes detract from the value of the bed by increasing the cost of mining, and an allowance is made in the final price in accordance with their character and extent.

ALLOWANCE FOR OTHER FACTORS.

In addition to the factors that have been specifically considered, many other factors are taken into account in valuing the land in any field. Of these the one for which the largest allowance is likely to be made is that of uncertainty. In some fields it has been possible to obtain measurements on the coal along its outcrop at points a quarter of a mile or less apart, and some of these measurements are supplemented by others made in drillings at points "back" from the outcrop, so that in such places it is possible to determine the "habit" of the bed with some degree of certainty. In other places, especially in coal fields covered with a blanket of glacial deposits, or in broad valleys where the coals are under an alluvial cover, or in other fields where, owing to almost continuous burning along the outcrops, it is difficult to get accurate information as to the thickness of the beds, an allowance is made for uncertainty—an allowance that may take the form of a greatly reduced estimated thickness of the bed or, as is more common, of a restriction of the assumed area of workable coal. It has been found that the coal of certain fields was originally deposited with more regularity in some belts and areas than in others, and in many places the coal was deposited with great regularity around the edge of a basin but not in its center. Allowance is made for the possible thinning of the coal in all such places if exact data are not at hand, and the tract is classed either as noncoal land or as coal land of the minimum value. Many other factors are taken into account, such as known poor roof or floor, which may seriously affect the cost of mining and the value of the coal in place. Allowance is made for the extra cost of mining beds that include partings by making deductions for partings, it being assumed that the extra cost due to the partings eats up the profits on an equal thickness of coal.

REDUCTION FOR DISTANCE FROM RAILROAD.

Distance from railroads very largely affects the value of coal land. In fixing the value of Government coal land, however, distance from railroads is not taken into account, their value being based on that of the coal itself, but, in accordance with the law, the price so fixed is automatically reduced one-half for all lands lying more than 15 miles from a railroad in operation. Some land that contains coal beds, though within 15 miles of a railroad, can not be reached by a railroad switch without going either around or over a high mountain, so that by either route its distance from the railroad practically exceeds the 15-mile limit. Such land is treated as if it were beyond the 15-mile limit and its price is reduced one-half, though not below the legal minimum—\$20 an acre.

MAXIMUM PRICE.

In view of the uncertainty that may exist concerning many features of an undeveloped coal field, even if the evidence seems conclusive that it contains a large volume of coal, the maximum price of coal land is fixed by the regulations at \$300 an acre, except that if the field in which the land is situated contains very large mines, and if the coal is well known in the market and its adaptability to different uses has been demonstrated, the price of the land is computed from the value of the coal it contains, whether it exceeds \$300 an acre or not.

REVIEW OF CLASSIFICATION.

According to the regulations the classification of any land as coal land is subject to review by the Secretary of the Interior, but the person making the application for review must present facts that show clearly and specifically that the land is not coal bearing in the sense of that term as it is defined in the regulations. The facts set forth in nearly all applications for review and reclassification of coal land simply show that no coal can be seen outcropping on or close to the land and that no coal has been found in drilling wells for water on or near the land. Before such applications are filed request should be made of the Geological Survey to state the basis of the classification, for a large percentage of the coal land has been classified as such because it is underlain by coal at depths of 500 feet or more, whereas the rocks at the surface contain no coal and may be of entirely different age from the underlying coal-bearing rocks. Data presented in a request for reclassification have determinative value only if they differ from data already in the records of the Geological Survey.

REGULATIONS FOR THE CLASSIFICATION AND VALUATION OF PUBLIC COAL LANDS.

The following regulations were approved February 20, 1913, by Secretary of the Interior Fisher:

I. CLASSIFICATION.

1. Land shall be classified as coal land if it contains coal having—

- (a) A heat value of not less than 8,000 B. t. u. on an air-dried, unwashed or washed, unweathered mine sample.
- (b) A thickness of or equivalent to 14 inches for coals having a heat value of 12,000 B. t. u. or more, increasing 1 inch for a decrease from 12,000 to 11,000 B. t. u., 1 inch for a decrease from 11,000 to 10,500 B. t. u., 1 inch for each decrease of 250 B. t. u. from 10,500 to 10,000, and 1 inch for each decrease of 100 B. t. u. below 10,000.
- (c) A depth below the surface for a bed of coal 6 feet or more thick of not more than 100 feet for each 300 B. t. u. or major fraction thereof, and for a bed of minimum thickness for that coal a depth of not more than 500 feet, and for beds of any thickness between the minimum and 6 feet a depth directly proportional to that thickness within these limits, provided that, if the coal lies below the depth limit but within a horizontal distance from the surface not exceeding 10 times the depth limit, or if its horizontal distance from the foot of a possible shaft (not deeper than the depth limit) plus 7.5 times the depth of such shaft does not exceed 10 times the depth limit, the land shall be classified as coal land; provided, further, that the depth limit shall be computed for each individual bed, except that where two or more beds occur in such relations that they may be mined from the same opening the depth limit may be determined on the group as a unit, being fixed at the center of weight of the group, no coal that is below the depth limit thus determined to be considered.

2. Classification shall be made by quarter-quarter sections or surveyed lots except that for good reason classification may be made by 2½-acre tracts or multiples thereof described as minor subdivisions of quarter-quarter sections or rectangular lotted tracts.

II. VALUATION.

3. For purposes of valuation the price per ton for a noncoking, nonanthracite coal 6 to 10 feet thick shall be one-tenth of a cent for each 1,250 B. t. u.:

- (a) Provided that the price per ton may be increased by not more than 100 per cent if the coal is coking, smokeless, or anthracitic or has other enhancing qualities; or it may be decreased for high sulphur or ash, friability, or nonstocking or other qualities that reduce the value; and
- (b) Provided, further, that if the coal in one bed is over 10 feet thick the price on each foot above 10 feet shall be reduced 1 per cent for each such foot (thus the reduction will be 1 per cent on the eleventh foot, 2 per cent on the twelfth foot, and so on); or if the coal is less than 6 feet thick the price shall be reduced by

multiplying the normal value by $\frac{4+t}{10}$, where t equals thickness in feet; and

- (c) Provided that where the thickness of any bed varies irregularly its computed thickness (CT) over any area shall be equal to the average of the measurements (AM) less the sum of the differences between each measurement and the average of the measurements (SD) divided by the sum of the measurements (S):

$$CT = AM - \frac{SD}{S}$$

4. The value of any acre within 15 miles of a railroad in operation shall be determined at the rate per ton prescribed above on an estimated recoverable tonnage of 1,000 tons to the acre-foot:

Provided that if the coal is in several beds having an aggregate thickness of more than 10 feet if beds less than 6 feet thick are considered at the reduced thickness as prescribed above, the value due to each foot above 10 feet shall be reduced 1 per cent for each such foot (as in computing the price per ton on a single thick bed) up to a thickness of 80 feet, above which any additional thickness shall be valued at 80 per cent of the normal value.

5. This price shall be decreased one-half if the land is more than 15 miles from a railroad in operation, or if it is within that limit but inaccessible owing to topographic conditions; but no land shall be valued at less than the legal minimum price, nor shall the price of any land exceed \$300 an acre except in districts which contain large coal mines and where the character and extent of the coal are well known.

6. Within the above restrictions a graded allowance shall be made for increasing depth, and allowance may be made for any special conditions enhancing or diminishing the value of the land for coal mining.

7. If only a part of a smallest legal subdivision is underlain by coal the price per acre shall be fixed by dividing the total estimated coal values by the number of acres in the subdivision, but this price shall not be less than the minimum provided by law.

8. When lands which were at the time of classification more than 15 miles from a railroad are brought within the 15-mile limit by the beginning of operation of a new road, all values given in the original classification shall be doubled by the register and receiver.

9. Review of classification or valuation may be had only on application therefor to the Secretary, accompanied by a clear and specific statement of conditions not existing or not known to exist at the time of examination.

RESTORATION.

After the classifications and valuations are completed the lands are restored to entry. Those that contain no coal resume the status that they had prior to the withdrawal. The coal lands, after restoration, may be acquired under the coal-land laws at the valuation prices, surface entry under the agricultural-land laws and the State selection

acts being permitted at any time prior to their alienation under the coal-land laws. A typical order of restoration is given below.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
Washington, February 12, 1913.

The honorable the SECRETARY OF THE INTERIOR.

SIR: The classification of the lands listed below, which are included in an existing withdrawal, has been completed and reported to the Land Office, and I therefore recommend the submission to the President, for appropriate action, of the following order of restoration, involving 284,000 acres, all noncoal. These lands are not included in petroleum or phosphate reserves or in national forests, but part are within a power-site reserve.

Very respectfully,

GEO. OTIS SMITH,
Director.

FEBRUARY 18, 1913.

Respectfully referred to the President with favorable recommendation.

WALTER L. FISHER,
Secretary.

ORDER OF RESTORATION.

Coal-land restoration—Idaho No. 10.

So much of the order of withdrawal made heretofore for the purpose of coal-land classification, namely, Idaho No. 1, as affects the lands hereinafter described is hereby revoked for the reason that the Director of the Geological Survey has classified these lands. This revocation does not affect withdrawals or reservations other than as above set forth.

Boise meridian.

T. 35 N., R. 1 E., all of township.

[Here follows the remainder of the land description.]

WM. H. TAFT,
President.

FEBRUARY 18, 1913.

FIELD WORK ON COAL LANDS.

GENERAL NATURE OF THE WORK.

The second general step in the process of classification is to obtain in the field the information there available that is necessary for the classification. Field work that is done expressly for the classification of coal land involves all research that is made in general geologic field work but gives special weight to certain factors. The information needed for classifying coal land relates to (1) location, (2) stratigraphy, (3) horizontal extent and thickness of coal beds, (4) vertical position, and (5) quality of the coal. These may be taken up in turn.

LOCATION.

In work done for classification all the points or features concerning which information is obtained in the field must be accurately located with reference to the land lines, for if locations are not exactly specified the information is of little value. For example, a geologist may study an outcrop of a 30-foot bed of coal, measure its sections, photograph it, and sample and analyze the coal to determine its quality or test it in any other way, but if, when he has done all these things, he can not tell whether the outcrop is in sec. 31 or sec. 32 of a given township, the information he has gathered is entirely valueless for purposes of classification. It is therefore necessary that all the features to which his information relates be accurately located on his field maps, with special reference to township and range lines, section lines, and quarter-section lines, and even accurately within the 40-acre tracts, as it is desirable to know exactly how many acres of the forty are underlain by coal in order to determine the value of that particular forty. The methods of survey by which the geology is tied as accurately as possible to the public-land net have been described in a preceding chapter.

STRATIGRAPHY.

The first purpose of gaining a thorough knowledge of the stratigraphy is to be able to recognize groups of rocks that are coal bearing elsewhere or to recognize other rocks that the wide experience and knowledge now available concerning the geology of the Western States have shown not to be coal bearing. The second purpose is to determine, from such data as may be obtained on the surface, the "lay" or structure of the coal-bearing formation and the groups of coal beds it contains.

Just as in the Eastern States it has been found that workable coal beds are confined to a particular part of one large group of rocks, which has long been designated the "coal measures," so in the West it has been found that workable coal beds are confined to relatively few groups of rocks, which are separated usually by great thicknesses of other rocks that are nowhere known to contain workable coal beds. As the sedimentary rocks of the West consist mainly of sandstones, shales, and limestones, those of like lithologic character being similar to one another in general appearance, the particular sandstones and shales with which the coal beds are associated can as a rule be distinguished only by means of the fossil plants or animals that are associated with them. Thus it has been found necessary to employ the services of several experienced paleontologists to examine the fossils associated with the rocks and from these fossils to determine the age of coal-bearing formations.

The first step of the geologist who has been sent into a field or area that is known or has been reported to contain workable coals is usually to determine what groups of rocks occur in that region and then, knowing the groups of rocks that contain workable coal beds in other places, to concentrate his attention on those groups, hunting for coals in them. Having found the coals his next work is to determine the number of groups of coals, as the same territory may contain two or three or even more coal-bearing formations, though usually they occur in different parts of the same field. His next step is to examine the several coal-bearing formations in order to determine, if possible, the number of coal beds in each. This work naturally leads to the determination of the areal extent and thickness of the beds.

EXTENT AND THICKNESS OF COAL BEDS.

Coal is a rock that has been formed from vegetal matter. The vegetation may have grown where the coal bed is now found, much as it grows in the great peat bogs of Europe or some of the large swamp areas of this country, or it may have been washed or drifted from the place where it grew to the place where it now occurs as coal. In changing from a mass of decaying vegetal matter to a bed of coal its volume has decreased and its weight per cubic foot has greatly increased. It has also lost many of the elements of the plants, especially the moisture they contained, and if during its formation the coal bed was inundated by muddy waters its vegetal matter may have been overlain or intermingled with sand or mud. This material may have been added in small quantities at frequent intervals, simply rendering the coal "dirty," or it may have come in at long intervals and then in large quantity so as to form a blanket of mud or sand, which, being covered by renewed accumulations of vegetal matter, becomes a parting of clay or sandstone in the coal bed. In a few places a single coal bed has been deposited in a formation, and thousands of feet of other rocks have been laid down beneath and above it, no other coals having been formed. More frequently, however, where coal-forming conditions have existed they seem to have recurred in such a way that a succession or series of coal beds are laid down in the same area. In one region most of the coals in a group deposited in that way may be thicker in the same general area, and all the beds may tend to thin away from that area. In another region one bed of a group may be thicker in one locality and a higher bed of the same group may be thicker in another locality.

Coal beds vary greatly in extent, ranging from pothole fillings having about the shape though not the size of a kettle to flat-lying beds thousands of square miles in extent. In Missouri a number of coal beds have a thickness in places of 90 feet or more and

an areal extent of only a few hundred feet or less, being simply fillings of deep holes in the rock, similar in shape to the "pot-holes" that are so abundant around some waterfalls. In other places, as in the Sharon field of Ohio, the coal bed has the shape of a valley, with branches where side streams have come in, and a single mine may follow one of these valleys for some distance, the coal being confined to a width of perhaps a few hundred yards but extending indefinitely up and down the valley, which in some places winds tortuously. In still other places, as in the Block coal field of Indiana, the coal occurs in a succession of shallow basins, the beds having a thickness of 3 to 5 feet in each basin and thinning out to a few inches between the basins. The bottoms of the basins lie 20 to 30 feet below their rims. Some of these basins are so small and so close together that the coal from several of them is extracted by a single mine, the entries being cut through the rock from the lower level of one basin to the lower level of the next basin. Other basins have a length of 2 or 3 miles in a northwest-southeast direction and a width of one-half mile or more. Some of the individual beds can be traced from basin to basin and clearly recognized by peculiarities in the coal. In other fields the coal appears to have been deposited unevenly in little depressions that are scattered irregularly over a large territory and lie at various levels, so that it is not possible to trace a bed from one point to another, and each little basin must be considered as a unit. From these types of irregular and narrowly limited coal beds every gradation may be found to some of the relatively even and continuous beds of the West, the extensive beds of the central interior coal fields, or the Pittsburgh and other beds of the East, which have an outcrop line hundreds or even thousands of miles in extent and were laid down in a more or less continuous sheet, many of them covering thousands of square miles. Thus the Pittsburgh bed has a known extent of over 6,000 square miles and is found in isolated areas beyond the limits of the main bed. Other Appalachian coal beds are of much greater extent, some of them, as the Lower Kittanning, having many times the areal extent of the Pittsburgh bed, though not its regularity.

Certain coal beds in the Illinois fields have been traced without question as to their identification over a large part of that State, through a portion of western Kentucky, and through the entire length of the Indiana coal field. It is believed that many of the coal beds of the Western States are also traceable over large areas. Most of these widely extended coal beds have certain slight but definite features or peculiarities or are associated with other rocks of distinctive character, so that it is possible to recognize them at any point. The peculiarity of a bed may consist of some particular type of parting or arrangement of partings which may hold for long dis-

tances, or it may consist of the presence just above or below the bed of a stratum that has easily recognizable characteristics. In order to trace and identify some coal beds it is necessary to study their relations to one another. One of the main reasons for studying the stratigraphy is to identify if possible at the outset the group of coals studied, and in this work note should be taken of the determinations reached by the wide study of the same formations in previous seasons. For example, in the great coal field that covers much of western North Dakota and part of South Dakota, all of southeastern Montana and the great Powder River field of Wyoming, there are two coal-bearing formations—the Fort Union above, named from its early recognition at Fort Union in North Dakota, and the Lance formation below, named from the occurrence of those rocks on Lance Creek in Wyoming. The Fort Union coals are as a rule persistent; they have local thicknesses of 10 to 30 feet or more, and some of them can be traced for hundreds of miles along their outcrop, and individual beds can be recognized from point to point. On the other hand, the Lance coals occur as a rule in small lenses, most of them a fraction of a mile or a very few miles in extent. The coal in these lenses ordinarily is but little above the minimum workable limit and thins rapidly to nonworkable thickness in all directions. If the geologist knows that the coals in any particular area are in the Fort Union or Lance formation he knows what to expect concerning them, for if he finds that they are of Lance age and he is studying at the moment the coal at a point where it is workable, he is careful to trace it if possible in order to see how far it may extend before it becomes unworkable, so as to determine as closely as practicable the extent of that particular lens. If, on the other hand, he knows that the coal before him is of Fort Union age he attempts to determine, if possible, what particular coal bed in the Fort Union it is, and, assuming that he will find that same bed in a large part of the country ahead of him and that he will judge of its thickness by combining a great number of measurements made over a large territory, he does not with the same attention attempt to discover whether the coal pinches out a short distance on either side of the point where he is standing. In all of this work it is, of course, not safe to assume too much, for toward the south end of the Powder River field the beds of coal in the Lance formation increase in extent and thickness, so that they more nearly resemble those of the Fort Union formation, farther north.

It is not advisable to assume absolutely that, because in some area already examined a coal bed is very extensive and keeps the same thickness with great regularity, it will continue to be extensive and regular in territory that may be studied later. For example, the Pittsburgh bed, which maintains a very uniform thickness over a

large area in western Pennsylvania, becomes very irregular in southern Ohio, so much so that it has been wrongly identified, and it is only within a few years that the bed there identified as the Pittsburgh has been shown to be another coal higher in the series. Likewise, in the Illinois-Indiana field coal V, which is probably the most persistent bed in that field and can be traced along its outcrop for thousands of miles with great regularity, pinches out in parts of Greene County, Ind., close to other localities where it shows its greatest thickness; and, again, in Warrick County it loses its usual characteristic roof and is split into two distinct beds. In the same way many of the coals in the West that on casual scrutiny appear to be persistent prove, when studied in detail, especially in connection with mining operations or where close prospecting has been done with a drill, to vary considerably both in thickness and in distance apart. For example, at Castlegate, Utah, four beds are at one point separated by 50 feet, 20 feet, and 14 feet of strata, whereas a short distance away these intervening rocks pinch out and the four beds, which separately are on the average only about 3 feet thick, come together to make a single bed 12 feet thick. Drilling in that field has shown that all the beds tend to be very irregular, splitting and combining again and changing in thickness, so that in tracing them from drilling to drilling it may be found that though each core shows certain workable beds, yet a bed that is thick at one point is thin at the next. Detailed work in many of the eastern fields where extensive mining operations have afforded minute data in regard to the coal, or where thousands of dollars have been expended in drilling, has shown that even the most persistent of the beds are subject to variations, so that a bed which can be traced from one mine to another over a whole county and which may show a variation of only a few inches from mine to mine may suddenly, in mining parlance, "go to pieces." It is therefore the special work of the field geologist not only to locate the coal on the ground but to make as detailed a study as possible of its thickness and extent in order to learn just how far it maintains a workable thickness, how persistently it maintains a given thickness, and whether it is likely to vary greatly from point to point and also to determine, so far as he can, any or all of its features. Space does not permit the detailed description here of all the possible irregularities that may occur in a coal bed, for which the field geologist must be on the lookout.

In some fields the coal beds are exposed in cliffs or steep slopes in such a way that the coal may be seen almost continuously for many miles. In such places the geologist takes the opportunity to make a careful study of the regularity or irregularity of the coal beds with reference both to their thickness and to the variability or regularity

in thickness and in character of the intervening rocks and of the spaces between the beds. In regions in which the beds are not well exposed it may be possible, from a knowledge of the position of a bed with reference to other rocks which show on the surface, to determine exactly the position of the particular coal under consideration and, by means of a very small amount of digging, to expose the bed so that its thickness and partings can be measured. In some coal fields hundreds of such openings have been made in the study of the bed. In other fields the beds occur in rocks that weather down to soils rapidly, and it may be only where a coal bed crosses a stream or is otherwise exposed that it can be located or seen. It may be difficult to trace such a bed from point to point, and in some places where exposures are several miles apart it may be difficult or impossible to determine exactly its position. In other places beds may be traced readily, but the fact that they have been burned continuously along their outcrops makes it difficult to get accurate information concerning their character and thickness. It is of course possible to map the position of the coal bed in such places and it is then necessary, from such information as can be obtained concerning the thickness and character of the coal, to infer its character at points between these places. It is especially in such areas that a general knowledge of the "habits" of the bed or group of beds assists in their classification, for if it is known that a particular bed, whose burned outcrop has been traced with detailed measurements perhaps at only one or two places in a township, occurs at a certain horizon in a certain formation, it is possible to surmise whether it is regular or irregular in the broad area between these exposures, where no information on the bed itself can be obtained. Again, it may be possible, by making a careful study of a coal in a mining region, to apply the information to a wide area where but scanty information on the coal itself can be obtained. Wherever the coal is exposed the field man makes careful examination and measurement of every possible section, measuring down to the fraction of an inch, even though, where the bed is irregular, it is recognized that another measurement made a short distance away may be quite different. Where a bed is irregular special effort is made to obtain as many measurements as possible, in order to obtain average figures for use in the classification and valuation of the land underlain by that bed. In some places where the data are very meager, as in regions where the rocks crumble to soil and the land is largely meadow land, considerable time has been given to making openings on the coal because of the necessity of having actual information and measurements as a basis for classification.

ATTITUDE AND DEPTH OF THE COAL.

As already stated, the coal throughout wide areas lies entirely below the level of drainage—in places hundreds or even thousands of feet below—and the outcrops of the particular coal beds on which land is classified as coal land may be scores of miles away. It therefore becomes necessary for the field man to determine as accurately as possible not only the position of the coal outcrop with reference to the land lines and the thickness of the coal as exposed along the outcrop or the extent of the lenses, but also the depth of the bed beneath the surface and its attitude as it dips into the basin. He does this, first, by studying the inclination of the coal beds where they dip into the ground and, next, by studying the inclination and thickness of the other rocks that overlie them. As coal beds lie more or less nearly parallel with layers of sandstone, shale, and limestone, one of his duties is to determine how nearly the coal beds are parallel with these other rock layers. If he finds by observation at many points that there is very little variation in the interval, say 300 feet, between a limestone bed above and the coal bed that he is studying, he may assume that the dip of that limestone bed measured possibly at a point a mile back from the outcrop of the coal indicates the dip of the coal beneath that point at a level 300 feet below the surface. If, again, he finds that some other rock bed a thousand feet above the coal bed is parallel to it, he may assume that a measurement of the dip of that bed taken 5 or 10 miles back from the coal outcrop may indicate rather closely the dip of the coal bed itself 1,000 feet below. Hence the field geologist must not only study the details of the coal bed along its outcrop, but must also study the geology of the area back of that outcrop, especially with reference to the dip of the rocks. If, as sometimes happens, he finds that the space between a coal bed and the overlying rocks is variable, he can not compute the depth of the coal bed so closely. In some places all the rocks associated with certain coal beds, having the same great folds and basins, have been overspread by a blanket of other rocks that do not have the same structure. Such a blanket may completely hide not only the coal-bearing formation but the other formations that are associated with it and that have been folded in the same way. In such places it is only possible to infer from broad general knowledge of the field how deep the coals may lie below the surface.

QUALITY OF THE COAL.

The character and quality of a coal can be determined in part by a simple examination of the coal bed. Thus it is possible in most examinations to determine whether a coal is a lignite, a subbitumi-

nous, a bituminous, a cannel, or an anthracite coal. It may also be possible to estimate rather closely whether or not a coal contains a large amount of ash. Where small mines or prospects have been opened it may be possible, by studying the coal on the dump, to determine whether the coal can be shipped or stocked, or the extent to which it tends to crumble under the action of the atmosphere.

The final tests, however, are the chemical test, consisting of an analysis of the coal, which shows fully its percentage of the various heat-giving elements and of the ash and other elements that do not yield heat but detract from its value, and the test of its heat-giving value in the calorimeter. Experience has shown that coal of certain kinds—especially low-grade coal—changes in chemical composition very rapidly when exposed to the weather, so that in getting samples for analysis it has been found necessary, in order that the samples may be fairly compared and may form the basis of a uniform system of classification and valuation, that they be taken with great care in a uniform manner and that the treatment of each sample from the time it is taken until it is analyzed shall follow certain standards. To this end certain regulations have been prepared in regard to the method of obtaining coal samples for analysis and are consistently enforced. These regulations in brief are as follows:

1. Select a fresh face of unweathered coal at the point where the sample is to be obtained and clean it of all powder stains and other impurities.

2. Spread a piece of oilcloth or rubber cloth on the floor so as to catch the particles of coal as they are cut and to keep out impurities and excessive moisture where the floor is wet. Such a cloth should be about $1\frac{1}{2}$ by 2 yards in size and should be so spread as to catch all the material composing the sample.

3. Cut a channel perpendicularly across the face of the coal bed from roof to floor, with the exceptions noted in paragraph 4, of such size as to yield at least 6 pounds of coal per foot of thickness of coal bed; that is, 6 pounds for a bed 1 foot thick, 12 pounds for a bed 2 feet thick, 24 pounds for a bed 4 feet thick, etc.

4. All material encountered in such a cut should be included in the sample, except partings or binders more than three-eighths inch in thickness and lenses or concretions of "sulphur" or other impurities greater than 2 inches in maximum diameter and one-half inch in thickness.

5. If the sample is wet, it should be taken out of the mine and dried until all sensible moisture has been driven off.

6. If the coal is not visibly moist, it should be pulverized and quartered down inside the mine to avoid changes in moisture, which take place rapidly when fine coal is exposed to different atmospheric conditions. The coal should be pulverized until it will pass through a sieve with one-half inch mesh, and then, after thorough mixing, it should be divided into quarters and opposite quarters rejected. The operation of mixing and quartering should be repeated until a sample of the desired size is obtained. When the work has been properly done a quart sample is sufficient to send for chemical analysis. This sample should be sealed in either a glass jar or a screw-top can with adhesive tape over the joint and sent to the chemical laboratory for analysis.

Since the value of the land varies with the quality of the coal as determined by the chemist, his methods are briefly described here.¹ Immediately after the sample is received at the laboratory it is weighed and placed in a shallow tin pan in a large drying oven, in which a temperature of 30° to 35° C. is maintained. The sample remains exposed to currents of warm air in the oven until the loss between two successive weighings made six to eight hours apart does not vary more than 0.2 per cent. The loss of weight in the oven is called air-drying loss.

After being air dried the sample is crushed to a fine powder and thoroughly mixed. To determine the amount of moisture remaining in the coal after air drying, a 1-gram sample is heated for an hour at 105° C. and then cooled in a desiccator over sulphuric acid. The moisture in the sample is thus driven off, hence the percentage of loss represents the percentage of moisture in the coal. The remaining part of the sample is next used to determine the amount of ash in the coal. This determination is made by slowly heating the sample in a muffle furnace until all of the combustible matter is burned off. The remainder is ash. The volatile matter is determined from a fresh 1-gram sample in a 30-gram platinum crucible, with a close-fitting cover, heated for seven minutes over a Bunsen flame 20 centimeters high. The loss in weight minus the moisture at 105° C. is the weight of the volatile combustible matter. The sulphur is determined on a separate example by what is known as the Eschka method. The percentage of fixed carbon given in the analysis is the difference between 100 per cent and the sum of moisture, volatile combustible matter, and ash.

The calorific value of a coal, or the amount of heat that can be obtained from it, is the most important factor in classification and valuation.

The calorific value of coal is determined with a bomb calorimeter. The following is a brief description of the details of operation:

A 1-gram sample of coal (60-mesh) in a platinum tray is placed in the bomb and the lid is screwed down tightly against a lead gasket. Oxygen is forced into the bomb until the pressure is 18 to 20 atmospheres. The bomb, filled with oxygen, is placed in a brass bucket containing distilled water, the bucket having been previously placed in an insulated jacket.

The coal is ignited by electric current and is burned at once. The heat of combustion is transmitted through the walls of the bomb and is manifested in a rise in the temperature of the water. This rise in temperature is measured by a very delicate thermometer. The

¹The methods of analysing coal and coke are fully described in Technical Paper No. 8, Bureau of Mines, by Frederick M. Stanton and Arno C. Fieldner. The method outlined here is summarised from that paper.

quantity of heat given off by the burning of the coal is determined by multiplying the product of the weights of the metal and water in the apparatus and their respective specific heats by the rise in temperature. The result thus obtained is calculated into terms of calories and British thermal units.

PREPARATION OF MATERIAL.

The preparation of material by the field man, so that it may be considered to the best advantage in the work of classification and valuation, has already been considered in the chapter entitled "Preparation of data for classification," immediately preceding the discussion of the classification of coal lands.

PROCEDURE IN CLASSIFICATION AND VALUATION.

In the actual work of classification of coal lands each area under consideration must be treated individually, yet in general a definite line of procedure is followed.

The first step is to assemble all the available data, including not only the maps and reports of the geologists who may have made a special examination of the field, but the reports of any special agents of the Land Office who have been in that field, as well as all reports of geologists who may have visited the field at some earlier time (probably for some other purpose) and all other available information concerning the land or the coal it may contain. The land-classification board has a system of graphic records which show at once the existence of any reports on the field and give references to them, so that when the case is taken up all the data available are at hand. As a matter of fact the field man will usually have familiarized himself with all these earlier data and will be prepared to present them as may be necessary.

The second step is to scrutinize carefully all these data, and by their aid to take the action or to obtain the information listed under the following heads:

1. The number, names, character, and other features of the coal-bearing formations are determined. As most of these formations extend over large areas, some of them crossing several States, a general knowledge of the formations at once suggests the probable conditions to be found in the field studied, and that general knowledge may strongly affect the action to be taken in classification and valuation.

2. The number of coal horizons or groups of horizons is ascertained.

3. The thickness of each coal bed over the field is determined, if it can be traced. If each bed can not be traced the group of coals

is studied as a whole to determine from point to point the number of beds and their aggregate thickness and value.

4. The basing value per ton of the coal is computed by comparing its analyses and its obvious character with the standard scale. An average B. t. u. value having been fixed for the coals of the field or for the different groups of coals, the other qualities of the coal—such as its adaptability to coking or to stocking—are studied to determine whether they enhance that value or detract from it, and the price is raised or lowered accordingly.

5. If the field is small and the data are scattered the field may be studied as a unit. If the data are abundant in any township the coals in that township are studied by themselves, and, exceptionally, the variation in thickness may make it necessary to divide a township into belts or areas, in each of which a basing value of the groups is determined.

6. All sections of the coal are examined, and if the coal beds are split the equivalent thickness of a solid bed is computed and a memorandum of the results is placed beside the drawn section. Then further reduction is made for the reduced value of the bed, if it is less than 6 or more than 10 feet thick. If a bed is variable in thickness but varies so regularly that lines of equal thickness can be drawn on a map of the field these lines are so redrawn as to indicate the reduced thickness determined by allowance for their reduced value if the thickness is less than 6 or more than 10 feet. If the beds are of irregular thickness the average of the measurements taken is obtained, and by the use of the "modulus of irregularity" a computed average thickness is obtained for use in valuation.

7. The outcrops of the coals are examined to determine which are workable coals and especially to make note of the outcrop of the lowest bed or the bed covering the largest area. Where the coal lies in one or more lenses a computation of its gradation in thickness is made between points at one of which the coal is below the minimum thickness and at the other is above, to determine the position of the minimum. The limits of workable coal having been determined for certain points, the limits of the lenses of the coal are drawn on the maps. For isolated measurements at points where the bed is above the minimum limit the extent and character of the several lenses measured are determined, special formulas being applied where possible.

8. If the coal passes below the depth limit of workable coal the position of that limit is determined and indicated on the map.

9. The limit of workable coal having now been determined, a line is drawn on a plat along the 40-acre lines, or, where necessary, along the 10, 5, or $2\frac{1}{2}$ acre lines in the forty, to separate the area that con-

Oil and gas are composed for the most part of carbon and hydrogen, but they vary greatly in the proportions of these elements and in the way in which they are combined. The petroleum oils range from low-grade heavy oils containing much asphalt to high-grade light oils which contain a large percentage of paraffin and volatile constituents and little or no asphalt. The heaviest oil is chiefly valuable as fuel, for which it is used in its crude state. Progressively lighter oils are used less and less for fuel and more and more for the other products that are obtained from them. There is a general opinion that weight for weight the fuel value of light and heavy oils is about equal, but because of the value of the distillates from the lighter oils it may be stated in general that the lighter the oil the greater its value.

In classifying lands as to their probable content of oil and gas it must be borne in mind that oil and gas are mobile substances and that, owing to their mobility and to the resulting increased importance of gravitation, temperature, hydrostatic pressure, and capillarity, it is necessary to make certain variations from the type of procedure employed in classifying lands containing coal, phosphate, or other stable minerals. The mobility of oil and gas has, in many regions, permitted their migration through varying thicknesses of pervious strata to their present places of accumulation, so that the problem is not to discover where the hydrocarbons originated but rather where they have accumulated.

The present position of these accumulations depends mainly on the character of the strata, the attitude of the strata (commonly spoken of as the rock structure), the presence or absence of water, and the character and specific gravity of the oil. The fluid hydrocarbons do not, as is supposed by some, occupy underground lakes or reservoirs surrounded by walls of rock. Instead they saturate porous rocks in places where the geologic structure, the conditions with regard to underground water, and the succession of strata are such that the accumulations are sealed by relatively impervious beds. Thus, although the accumulations of oil or gas are called "pools," they are not to be confused with such pools as are formed by the collection of liquids upon the surface of the ground. The porous stratum in which the hydrocarbon collects is often spoken of as an oil or gas "sand," although it may in reality be sandstone, gravel, limestone, or a zone of fractured rock. Into this "sand" the hydrocarbon comes from one or another source, but if there is to be an accumulation of importance the migration of the oil or gas along this pervious bed must be stopped by a change in dip or by some other obstacle to continued progress, and, in addition, the reservoir thus formed must be sealed by strata that are relatively impervious,

such as compact shales, clays, or fine-grained sandy beds saturated with water.

The accumulations within the United States may be divided roughly into three classes, as indicated below.

1. Those occurring in strata of sandstone or limestone bounded above and below by rocks comparatively impervious to oil. The sandstone or limestone may be of broad or of very narrow extent, in some places comprising merely small lenses of porous material embedded in relatively impervious rocks, in others underlying hundreds of square miles of territory in comparatively regular beds. To this class belong the greater number of oil accumulations of this country.

2. Those occurring in porous strata, apparently lenticular, associated with the "salt domes" of the Gulf Coastal Plain.

3. Those occurring in fissures in shale, as in the Florence field of Colorado. The fracturing of other rocks, such as limestone and sandstone, affords favorable conditions for the accumulation of oil; but sandstone and, under certain conditions, limestone are capable of storing oil without fracturing, the fracturing merely increasing their capacity. A fine-grained shale, on the contrary, although capable of containing oil, does not permit its migration through the rock mass with sufficient rapidity for collection in wells unless the shale is broken by fissures, which serve as channels or reservoirs for the slowly migrating oil.

It may be stated as a fundamental principle that important accumulations of petroleum and natural gas are to be found only in stratified or sedimentary rocks. Regions in which the strata have been greatly disturbed or altered by intrusions of igneous rock are, as a rule, unfavorable to the accumulation of petroleum, because the attendant heat and fracturing would as a rule have had disastrous effects on volatile substances of this character. An interesting apparent exception has been noted in Ventura County, Cal., where oil to the extent of 5 or 6 barrels a day has been obtained from wells drilled in close-textured crystalline schist. Although the schist is underlain by granite, it is overlain at a distance of only a few hundred feet from the wells by Tertiary rocks which in the same general region are petroleum bearing. These relations suggest that the presence of the oil in the schist is due to infiltration from the Tertiary sediments through fractured zones rather than to origin in the sediments that were metamorphosed to form the schist.

In general, then, oil is found in sedimentary strata of greater or less extent and regularity. These strata were originally deposited by water in the ocean, in fresh-water lakes, or on great deltas practically at sea level. The beds were therefore horizontal, or nearly

horizontal, as first laid down, and where a series of beds was deposited one above another, there being no earth movement during the deposition, the several beds were parallel. After the beds of sand, mud, and marl were deposited and hardened into the resulting sandstone, shale, and limestone, they were in certain areas bent by earth movements into folds of various shapes, and it is about these folds that the accumulations of oil are found. The attitude in which the rocks lie, the shape of the folds, and the presence of faults or breaks in the strata constitute the rock structure.

In any consideration of the factors which control the accumulation of oil or gas the importance of the part played by the structure can hardly be overestimated. The fluid contents of porous beds obey the laws of gravitation and capillarity, separating and distributing themselves in the main in accordance with their specific gravities. If water, petroleum, and gas are, as is usual, present in petroliferous beds, the gas would as much as possible disengage itself from the fluid and rise to the highest point in the fold, while the water would endeavor to displace the petroleum and find a resting place as low down as possible. If the bed of rock is inclined and the water is under artesian pressure, it will be forced upward along the bed, the oil remaining above the water because of the difference in specific gravity. If the porous bed is continuous in dip to the outcrop, the gas and oil are likely to exhaust themselves at the outcrop in the form of seeps. If, however, the progress of the hydrocarbons up the dip is stopped by a fold in the bed, or by a fault which seals instead of opening the stratum, or by saturation of the bed with water, an accumulation takes place, the oil and gas remaining between the water down the dip and whatever has impeded their progress up the dip. This theory, which is known as the anticlinal theory, is in some form now accepted by practically all geologists, not as indicating absolutely the limitations of the occurrence of oil and gas but as expressing the general relations of their occurrence to geologic structure, subject to various modifying conditions. Other factors less well understood enter into the problem, such as the difference in the capillary attraction exerted between water and the rock particles and between oil and the rock particles and the differences in friction experienced by the two fluids in passing through the rock. There is much to be learned concerning the whole problem, but enough is known to make the study of any oil field of economic as well as scientific value.

If the rock containing the oil does not also carry water there is no force to impel the oil into the upfold or anticline. On the contrary, gravity tends to pull it downward and it collects in the adjoining downfold or syncline. This condition is found in some of the Pennsylvania fields.

Where the migration of oil is due to the pressure of dissolved or occluded gas in the absence of water saturation the oil will move in all directions until it is stopped by some impervious stratum, where accumulation takes place in apparent disregard of structure.

The simplest structure favorable to the accumulation of oil and gas is that of a symmetrical anticline having little or no pitch of the axis and moderately dipping flanks. If the requisite condition of porous oil-bearing rock adequately sealed by impervious beds is fulfilled and the strata are impregnated with water under moderate hydrostatic pressure, the hydrocarbons will, under ideal conditions, segregate in the axis of the fold and extend down the flanks a distance dependent on the quantity present. Farther down the flanks and in the troughs of the corresponding synclines water will as a rule be found. It is evident that, other things being equal, the extent of the productive area controlled by anticlinal structure is greater where the fold is broad and the dip of the strata on the flanks relatively low than where the fold is narrow and has steep flanks, for in the former case the gathering ground for oil and gas is much greater than in the latter. From the simple symmetrical anticline there are gradations on the one hand into domes pitching away from a central point and on the other hand through unsymmetrical folds to an extreme type in which one flank is vertical or overturned. In every symmetrical fold the boundary between an oil pool lying at the top of a fold and extending part way down the sides of the fold and the water saturating the rocks farther down is an approximately horizontal line, because as long as the fold is regular the water tends to rise to the same level all along it. If, however, there are minor irregularities on the sides of the fold these have their effect on the distribution of the oil, making the margin of the pool irregular or causing small pools to collect along the slope.

Structural features of other types are under certain conditions favorable for the accumulation of petroleum and natural gas. Among these may be mentioned monoclines, which present conditions favorable for the concentration of oil wherever there is a change in the rate of dip or an abrupt change in the strike of the rocks, shallow synclines where water is absent from the oil-bearing zone, and synclines where the oil and water are of nearly the same gravity. Unconformities where steeply dipping petroliferous strata are overlain by relatively impervious horizontal or nearly horizontal beds are also favorable. Faults are usually considered wholly unfavorable to the accumulation of oil and gas, and for areas where the dislocations are many and extensive this view is undoubtedly correct. However, in many places faults have quite the contrary effect. For instance, strike faults may cause a greater concentration of petroleum toward the crest of a fold, and dip faults in a series where there are many oil

sands may bring about communication between the different sands and have a notable effect on local production. In a series of uniformly dipping beds an oil sand which would normally crop out at the surface may be cut off by a strike fault and sealed beneath impervious beds and thus retain oil which would otherwise migrate to the surface and be dispelled. Moreover, faulting may produce fractured zones along which the oil or gas can migrate and in which it may collect. In a number of localities, as in some of the fields in Mexico, where intrusive dikes have pierced oil-bearing strata and consequently arrested the movement of the oil in certain directions, the petroleum has accumulated in apparent disregard of the structural features of the sedimentary series.

In many fields there is little or nothing at the surface to indicate the presence of valuable hydrocarbons below, but in many other fields there is ample indication of oil at the surface. The oil-bearing stratum itself may crop out and the oil ooze from it, giving to the rock a dark, greasy appearance and the odor of petroleum, or the oil may find its way to the surface from the oil pool below through some fracture of the overlying rock. Water charged with various salts or with sulphur may rise with the oil, so that a spring is formed. the oil floating as a brown scum on the surface of the water or in smaller quantity producing the brilliant iridescent sheen characteristic of petroleum. Gas may find its way to the surface and appear in "gas springs" or under certain conditions may produce the phenomenon of mud volcanoes. The place at which oil has come to the surface and evaporated through long periods of time may be marked by a deposit of asphaltum. In certain localities oil-bearing shales have been burnt to a pink or deep brick-red color or altered to a hard vesicular rock resembling scoriaceous lava. This metamorphism is due to the burning of the hydrocarbons that have impregnated the rock, and the presence of such rock therefore becomes an important surface indication of petroleum.

The stratigraphic occurrence of hydrocarbon minerals in the United States is by no means limited; on the contrary, petroleum in the solid, liquid, or gaseous form is found in greater or less quantity throughout the range of strata from the Cambrian to the younger members of the Tertiary series.

In general the commercially important accumulations of oil throughout the central and eastern portions of the United States are found in strata belonging to the Paleozoic era. In the great Appalachian field, which extends from the southern portion of New York along the western slope of the Allegheny Mountains to northern Tennessee, the accumulations of oil occur in strata ranging in age from early Devonian to late Carboniferous. In Ohio and Indiana petroleum is derived chiefly from rocks of Ordovician age, and in Indiana mainly

from Carboniferous strata. In the Mid-Continent field, which embraces Missouri, Kansas, and Oklahoma, the petroleum has accumulated in rocks of the Pennsylvanian and Permian series. In the Gulf field, which includes the Coastal Plain of Louisiana and Texas, the petroleum-yielding rocks are Mesozoic and Cenozoic in age, being assigned in part to Cretaceous and in part to Tertiary formations.

In the Rocky Mountain fields the productive formations range in age from late Paleozoic to late Mesozoic. The Wyoming fields present perhaps the greatest range of occurrence, yielding oil from strata belonging to the Carboniferous, Triassic, Jurassic, and Cretaceous systems. The Colorado and New Mexico fields thus far developed obtain their oil from strata included entirely within the Cretaceous, and the small quantity of oil produced in Utah is derived from rocks assigned to the Carboniferous system, although indications of oil are found at certain localities in the Jurassic and Cretaceous rocks.

In the Pacific coast region the important accumulations of oil are found chiefly in Cenozoic rocks, although in certain fields an output of local importance is obtained from late Mesozoic rocks. In Ventura County, Cal., the principal oil-yielding formations are classed as Tertiary and range in age from Miocene to Pliocene. Along the west side of the San Joaquin Valley the range is greater, the oil extending downward into the upper members of the Cretaceous system. In the Kern River field, on the east side of the San Joaquin Valley in Kern County, oil is obtained from rocks of late Miocene or Pliocene age. In Santa Barbara County the oil is derived chiefly from early Miocene rocks. In portions of Oregon and Washington small amounts of oil and gas have been obtained from rocks assigned to the Eocene and Miocene series.

Despite this wide distribution of fluid hydrocarbons the conclusion does not necessarily follow that accumulations of asphaltum, oil, or natural gas may be found in any area of sedimentary rocks, for such accumulations take place only where all the essential conditions governing origin, adequate storage facilities, and favorable structure are fulfilled.

CLASSIFICATION OF OIL AND GAS LANDS.

- The immediate purpose of the classification of oil and gas land is to withhold from entry all lands containing valuable deposits of fluid hydrocarbons pending the enactment of adequate legislation providing for their disposition. The ultimate purpose of the classification is to determine the position and extent of the areas whose value for their deposits of oil or gas, whether proved by actual drilling or indicated by favorable geologic conditions, is greater than their value for agriculture or other purposes and to provide for a disposition of the deposits in accordance with this greater value.

Classifications are made by the oil section of the land-classification board. This section consists of three geologists, in addition to the chief of the board. Each classification is based on data submitted by a field geologist, who is called into consultation at the meeting at which his data are considered. Other geologists having special knowledge of the area under consideration may also be consulted. The factors observed by the field geologist are reviewed in detail, and his inferences and conclusions are subjected to the severest tests of experience and theory. Each factor which can be conceived as having a bearing on the accumulation and present distribution of oil within the area under discussion is carefully considered in all its relations before an attempt at classification is made.

The record data submitted by the field geologists consist primarily of a map or maps showing the facts observed in the field. On these maps surface contours and drainage are indicated and the details of the areal geology of the region are clearly shown. The position of all petroleum seepages and indications is recorded, as well as the location, by appropriate legend showing the results obtained, of each well drilled within the area examined. All determinations of dip and strike are shown, also the axial lines of all anticlines and synclines, with the direction and amount of pitch of each fold. The location of all land corners found is likewise noted, in order that the classification may conform to the established system of land surveys. Structure sections are necessary to explain complicated structural conditions and indicate the relative thicknesses of the formations and the position of the productive zones. Underground structure contours must be drawn to show the relative position of the principal oil-yielding zones above or below sea level, in order that the approximate depth of the oil zone beneath any desired point in the field may be readily determined when the elevation of the point above sea level is known. In a field where considerable development work has been done the preparation of the data should include the plotting of all available well records and the correlation, if possible, of the several oil-yielding zones.

The principal factors considered by the board in determining the classification of an area are the stratigraphy, the structure, the continuity and character of the oil sands, the quality of the oil, and the presence or absence of water. In many fields the productive sands are confined to a single geologic unit, the formations above and below being uniformly barren. It is therefore necessary to know not only the number and relation of the productive zones in a particular succession of strata but also the geologic system or series and, if possible, the formation or group to which these zones belong. The assignment of productive zones to a definite formation or group outside of which the strata are known to be barren constitutes an im-

portant step in the classification, the productive portions of the field being thus limited to the areas underlain by the petroliferous units and the areas not so underlain being at once disregarded as having no prospective value for oil.

As it is the structure of the petroliferous strata which largely determines the place of accumulation of oil and gas, it is apparent that a detailed knowledge of the structural conditions is absolutely essential to classification. In the classification of areas whose structure is anticlinal all lands are classified as oil bearing which lie along the axes of the anticlines or which are so located on the flanks that the oil sand underlies them within an arbitrarily chosen limit of depth. This limit may be the depth below which it is estimated that drilling can not be profitably carried because of mechanical difficulties, or it may represent the distance from the axis beyond which it is considered improbable that oil or gas in valuable quantities has accumulated. In monoclines similar considerations limit the distance down the dip to which classifications as oil land are carried. In the rarer synclinal accumulations the width of the zone classified as oil bearing depends mainly on what is known regarding the quantity of oil present.

The thickness and porosity of the reservoir rock are important factors to be considered with regard to the production and life of the wells, but their bearing on classification is subordinate, for classification is concerned with the boundaries of productive areas rather than with estimates of probable production. The continuity of the oil-bearing zone is, however, an important factor in classification, though, unfortunately, it is one whose exact value can rarely be determined, because of the difficulty of obtaining adequate data on the subject. In many areas of Tertiary rocks, where lateral variations in lithologic character within short distances are to be considered the rule and not the exception, changes in the thickness and extent of the oil-bearing zones must be expected, and although field examination may show the general trend of the variations in a certain region, local variations can seldom be predicted in advance of drilling. A factor of uncertainty is thus introduced, which may now and then result in an erroneous conclusion and give rise not only to adverse criticism of a particular classification but even to sweeping and unjust condemnation of the entire method of procedure.

The quality of the oil obtained in a given field is considered in classification mainly with regard to its bearing on distribution. In general the greater the specific gravity of the oil the slower will be its migration, the less complete its separation from the associated water, and the lower down on the flanks of the folds its resting place; and, conversely, the less the specific gravity the more rapid the rate of migration, the more complete the segregation, and the higher in

the folds the ultimate place of accumulation. Experience has shown that only under exceptional conditions may considerable accumulations of light paraffin-base oils be expected in monoclines, although in many places the monoclinical structure lends itself to the accumulation of heavy asphaltum-base oils.

The presence or absence of water in the formations of an oil-bearing region is a factor in the classification only as it affects the accumulation of the hydrocarbons, determining very largely their relation to the structure, as already explained. Whether or not it is present in the petroliferous strata must be known before a satisfactory classification can be made.

The maximum depth at which accumulations of oil or gas will warrant the classification of an area as oil land is a matter that demands careful consideration for each field. The factors that determine this depth limit are primarily the richness and the continuity of the oil-bearing zones, secondary consideration being given to the quality of the oil, present market conditions, and transportation facilities. Thus in certain areas where production is large and the oil-yielding zones are believed to continue productive to considerable depth, lands beneath which the productive zone lies at a computed depth of 5,500 feet have been classified as oil lands. On the other hand, in areas where the geologic conditions preclude a large accumulation of oil and indicate a doubtful continuity of the oil-bearing zones, depth limits as low as 3,000 feet have been fixed. That quality, market, and transportation facilities should receive only incidental consideration becomes evident when it is realized that deposits of low-grade oils that can not now be commercially exploited may, in the not distant future, as a result of improvements in methods of drilling and refining, become important contributors to the Nation's fuel supply; that the use of oil is practically just beginning, and it appears certain to build for itself a market far greater than it at present commands; and that with the advance of settlement or the beginning of production transportation facilities will be provided for fields now remote and essentially undeveloped. To many persons a maximum depth limit of 5,500 feet appears excessive, but to one who has acquainted himself with the rapid progress in well-drilling methods and machinery during the last decade this limit is far from unreasonable. In many of the California fields wells drilled to depths of 3,500 or 4,000 feet are by no means uncommon, and in foreign countries and at a few localities in the United States wells more than 5,000 feet deep have been drilled. In the Kern River oil field, California, one well has a depth of 5,135 feet; in the Midway field of the same State a well whose depth is slightly more than 5,000 feet is reported; and in the vicinity of Los Angeles a well was

recently completed at a depth of approximately 5,200 feet. In western Pennsylvania one well more than 5,500 feet in depth has been drilled, and another, not yet completed, has been sunk to a depth of more than 6,000 feet. The effect of a few more years of improvement in drilling methods on the development of deep-lying oil deposits can be inferred only from the history of the past, but in land classification, which seeks in a measure to foresee and provide for future conditions, this progress can not be ignored.

When a conclusion has been reached by the board as to the portions of the field presenting conditions favorable for oil and gas accumulation, when a depth limit of profitable extraction has been fixed, and when the boundaries of the favorable and unfavorable areas have been determined and translated into terms of legal subdivisions of the land surveys, withdrawal or restoration orders are prepared and forwarded by the Director to the Secretary of the Interior and the President for final action. Two general types of withdrawals are made—first, preliminary withdrawals, based on more or less meager information, and, second, withdrawals made after field examination.

The usual type of oil-land withdrawal order, based on field examination, closely resembles that used in the withdrawal from public entry of lands valuable for their phosphate content. An example of an order of withdrawal of phosphate lands is given on page 133. Two special petroleum reserves have been created in the State of California in order to retain in Government control bodies of oil-bearing lands containing what are believed to be sufficiently large reserves of fuel oil to provide for the future needs of the United States Navy. An example of an order creating a naval petroleum reserve is appended.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
Washington, August 8, 1912.

The honorable the SECRETARY OF THE INTERIOR.

SIR: In accordance with your instructions to recommend for inclusion in a special reserve a compact body of public lands containing an ample supply of fuel oil for the use of the United States Navy, I have prepared and recommend for submission to the President the following order of withdrawal, involving approximately 38,068 acres in the Elk Hills, Kern County, Cal.

Very respectfully,

GEO. OTIS SMITH,
Director.

AUGUST 10, 1912.

Respectfully referred to the President with favorable recommendation.

WALTER L. FISHER,
Secretary.

ORDER OF WITHDRAWAL.

Naval petroleum reserve No. 1.

It is hereby ordered that all lands included in the following list and heretofore forming a part of petroleum reserve No. 2, California No. 1, withdrawn on July 2, 1910, from settlement, location, sale, or entry, and reserved for classification and in aid of legislation under the authority of the act of Congress entitled "An act to authorize the President of the United States to make withdrawals of public lands in certain cases" (36 Stat. 847), shall hereafter, subject to valid existing rights, constitute naval petroleum reserve No. 1, and shall be held for the exclusive use or benefit of the United States Navy until this order is revoked by the President or by act of Congress. To this end and for this public purpose the order of July 2, 1910, is modified and the withdrawal of that date is continued and extended in so far as it affects these lands.

Mount Diablo meridian.

T. 30 S., R. 22 E., sec. 24, all.

[Here follows the remainder of land description.]

WM. H. TAFT,
President.

SEPTEMBER 2, 1912.

The preliminary withdrawals are made as a first step in classification and are based on recommendations of Survey geologists or of field agents of the General Land Office. A few such withdrawals have been based on petitions filed by residents of the community in which the occurrence of oil is suspected. The purpose of the withdrawals is primarily to withhold the lands from disposition pending their examination and classification. Because of the lack of definite geologic data most of the preliminary withdrawals of necessity embrace areas larger than those ultimately found to be valuable.

As soon as practicable after preliminary withdrawal the lands are examined geologically, and from the data obtained in this examination, presented and considered as already described, decisions as to the probable productive and nonproductive portions of the area are made. The areas classified as nonoil land are promptly restored and become subject to entry and disposition as if no withdrawal had been made.

The following order illustrates the form in which such restorations are made:

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
Washington, September 9, 1912.

The honorable the SECRETARY OF THE INTERIOR.

SIR: Field investigation by the Geological Survey indicates that the lands listed below do not contain deposits of oil or gas. The following order of restoration, which involves 133,626 acres, is therefore recommended for submission to the President for appropriate action. A small part of these lands is

within national forests, but none are included in public water reserves, coal, phosphate, or power-site withdrawals.

Very respectfully,

GEO. H. ASHLEY,
Acting Director.

SEPTEMBER 21, 1912.

Respectfully referred to the President, with favorable recommendation.

SAMUEL ADAMS,
Acting Secretary.

ORDER OF RESTORATION.

Petroleum restoration No. 12—California No. 7.

So much of the orders of withdrawal made heretofore for classification and in aid of legislation affecting the use and disposition of petroleum lands, namely, reserves No. 2, No. 18, and No. 20, as affects the lands hereinafter described is hereby revoked, for the reason that the Director of the Geological Survey reports that the lands are not valuable for the purpose for which withdrawn.

And it is further ordered that all such lands not otherwise reserved or withdrawn are hereby restored to the public domain and shall become subject to disposition under the laws applicable thereto upon such date and after such notice as may be determined upon by the Secretary of the Interior.

Mount Diablo meridian.

T. 16 S., R. 11 E., sec. 21, N. $\frac{1}{4}$ of SW. $\frac{1}{4}$, SE. $\frac{1}{4}$ of SW. $\frac{1}{4}$, S. $\frac{1}{4}$ of SE. $\frac{1}{4}$.
[Here follows the remainder of the land description.]

SEPTEMBER 23, 1912.

WM. H. TAFT,
President.

The areas classified as oil land remain withdrawn pending the enactment by Congress of appropriate legislation for the disposition of oil and gas deposits.

PHOSPHATE LANDS.

USE OF PHOSPHATE.

Phosphorus is one of the mineral elements that are essential to plant growth and therefore necessary to make soils productive, and it is one of the three most likely to become exhausted by continued removal in crops taken from the soil. Work at the agricultural experiment stations in Illinois, Ohio, and Wisconsin has shown that lands under cultivation in these States during the last half century have been depleted of one-third of their original content of phosphoric acid. This depletion per acre annually is equivalent to the

phosphoric acid contained in 60 pounds of high-grade phosphate rock. At this rate 12,000,000 tons of high-grade phosphate rock, approximately four times the production in 1911, or one-third the total marketed production in the United States from 1867 to 1911, would be required each year simply to offset the depletion of the 400,000,000 acres of cultivated land in the United States, the question of increasing the present agricultural yield not being considered.

Phosphate or rock phosphate is a mineral substance made up of lime and phosphoric acid and is the principal source of the phosphate of commerce. Its value is becoming more apparent and more clearly recognized in the United States, not only through the decreasing yield per acre of cultivated lands but also through the discovery of the fact that some virgin lands are deficient in this essential to plant growth. The marketed production of phosphate rock in the United States increased from 448,567 long tons in 1888 to 11,900,693 long tons in 1911. The rock phosphate is used as raw rock flour (or "floats") or in the form of a superphosphate, which is made by treating the rock with sulphuric acid.

LANDS CONTAINING PHOSPHATE.

The commercially available phosphate deposits of the public domain are those in Florida and those of the western fields, which, so far as investigated at present, are confined to the States of Idaho, Montana, Wyoming, and Utah.

Deposits of phosphate in the Rocky Mountain States were first discovered in northeastern Utah and southeastern Idaho, in the vicinity of the Idaho-Utah-Wyoming line. From this locality the deposits have been traced south, east, and west halfway across the States of Idaho, Utah, and Wyoming and northward to the vicinity of Helena, in west-central Montana, so that the phosphate beds now known cover an area extending about 220 miles from east to west and 420 miles from north to south. Of course only a small part of this territory is underlain by deposits that are commercially valuable.

Deposits of phosphate rock exist also in Tennessee, South Carolina, and Arkansas, but these deposits are on lands that have passed into private ownership. The production of Tennessee is increasing, that of Florida appears to have about reached its maximum, the South Carolina output is diminishing, and the Arkansas deposits are of low grade. For these reasons the largest future production must come from the western fields, where the deposits are chiefly on the public lands, although Florida will remain an important factor in production for many years to come.

PHOSPHATE RESERVES.

In order to prevent the alienation of the phosphate deposits on the public lands until Congress shall provide a law for their disposition that will encourage development under conditions favorable to the public interests, the known phosphate lands remaining in Government ownership have been temporarily withdrawn from entry. The reserves thus created embrace lands in the phosphate belt of Florida and in Utah, Idaho, Wyoming, and Montana.

FLORIDA RESERVES.

The deposits in the Florida reserves include two important kinds of phosphate—the hard rock and the land pebble; the latter doubtless was derived from the former. Deposits of both these types are found near the surface and are mined after removal of the soil cover or overburden. The pebble deposits are fairly regular in thickness, but the hard rock occurs in irregular pockets in the limestone of which it is supposed to be a residual product. The pebble deposits cover a large area, mainly in southwest-central Florida; the hard-rock deposits are distributed through the northwestern part of the State.

The hard-rock phosphate is sold on a guaranty of 77 per cent of tricalcium phosphate (the bone phosphate of commerce) and the pebble phosphate on guaranties of 60 to 75 per cent.

The prospecting or geologic mapping of these practically flat deposits in a region of slight relief is in most places complicated by the presence of overburden, so that any investigation of undeveloped portions is conducted principally by systematic drilling.

WESTERN RESERVES.

The phosphate deposits in the western reserves consist of rock phosphate occurring in beds interstratified with other rocks, in much the same way as coal occurs. The beds over 4 feet thick containing 70 per cent of tricalcium phosphate are from one to three in number in different places. These are interbedded with yellowish to brown phosphatic sandstone and shale and here and there with thin beds of dark limestone. The shale contains from 25 to 60 per cent of tricalcium phosphate and is doubtless of future economic importance. The phosphatic series ranges from less than 6 feet to about 180 feet in thickness and usually lies between a light-colored sandy limestone of variable thickness and a white, brown, yellow, or dull-black cherty limestone averaging 225 feet in thickness. The chert overlies the phosphatic beds where the strata are in normal order, but in places the beds have been turned completely

over in the intense folding that has occurred. The phosphate deposits therefore not only lie flat but stand at various inclinations, and they lie at great depth except where the long-continued action of the elements has worn away parts of the rock folds. These folds are of two principal types—upfolds, or anticlines, and downfolds, or synclines. In some places the folding has been moderate in amount and the folds are long, regular wrinkles. In other places the folding was so intense and the wrinkles were so sharp and extensive that the beds are broken or “faulted” and come together in irregular order. Faults may and in many places do sharply separate phosphate from nonphosphate land, and where such faults are concealed by later deposits, such as gravels, they may lead to an apparently unwarranted difference in the classification of adjoining and seemingly similar tracts. Two 40-acre tracts in a section may in reality be underlain by phosphate and the remaining tracts may be barren, although the surface character of all may be exactly similar, so that it is necessary that the field examinations, the nature of which is more fully explained elsewhere, should involve more than a study of specific tracts.

The phosphatic series is composed of rocks which wear away easily under the action of the elements, and its outcrop is therefore inconspicuous; but the rocks immediately above and below it are resistant and in many places stand out in ledges that are easily traced. The field surveys on which the classification of the lands is based are made with sufficient detail and accuracy to determine the distribution of phosphatic beds relative to 40-acre tracts or other legal subdivisions, the thickness and character of cover, and the quality and thickness of rock phosphate. The determination of the factors last named has in places involved the actual prospecting of the deposits by deep trenches, the longest of which was over 400 feet long. Certain other preliminary surveys of a reconnaissance nature have been made in order to acquire data for classification and preliminary modifications of the reserve boundaries.

The estimated quantity of high-grade rock (containing 70 per cent or more of tricalcium phosphate) included in the area surveyed in detail to date is more than 3,000,000,000 long tons, yet it is possible that such an estimate, based solely on information collected along the outcrop of the beds, may be excessive. Below the surface the brown phosphate of Tennessee rapidly becomes lean and grades into the phosphatic limestone from which the phosphate is supposed to have been concentrated by weathering. The phosphate deposits of the western reserves may ultimately be found to show a similar change, although they do not exhibit clear evidence of such concentration

but in the main have the characteristics of original bedded deposits, probably in part of purely chemical and in part of organic origin. They have therefore been inferred to have practically the same richness underground that they show at the outcrop. However, in view of the unproved value of the deeper portions of the phosphate beds it is advisable that they be sampled by deep prospecting before any plan for the final disposal of the lands is adopted. If such prospecting shows that the greater part of the rock included in the estimates is relatively of low grade it will be self-evident that the exhaustion of the phosphate resources is not so distant as it now appears and that the value of the outcropping portions that are now known to include high-grade phosphate rock is much greater than is at present suspected.

SUMMARY OF PHOSPHATE SITUATION.

The question of the adequacy of our phosphate resources for our own future needs had been mentioned by several authorities prior to the conference of the governors in 1908, in which the discussion of this and kindred topics drew public attention to the situation. At this conference the possibility that foreign investors might acquire the better-known and supposedly richer portions of our deposits was suggested, the wisdom of permitting the exportation of so essential a quasi-public commodity was questioned, and the desirability of an early examination of the available supplies was emphasized. In part as a result of these indications of public interest, in part as a continuation of the policy already adopted in reference to coal lands, and in part because of the legal dilemma existing in the western fields through the inadequacy of the laws governing the disposal of mineral land the Secretary of the Interior, on December 10, 1908, withdrew from entry about 7,000 square miles of public land in Idaho, Utah, and Wyoming, pending an examination of their phosphate resources. In the following summer the United States Geological Survey began the examination of these lands and the investigation has been continued up to the present time, some 4,000 square miles having been examined in a preliminary way and about 2,500 square miles surveyed in detail.

The first withdrawal was based partly on information collected by the Hayden Survey in 1877 and partly on later detailed and reconnaissance examinations made by the United States Geological Survey. Field work done subsequent to this withdrawal revealed the regularity and the character of the phosphate deposits, so that it has been possible not only to revise the estimates of the reserves in the area actually examined since the first withdrawal but also to make a closer interpretation of the information gathered by the earlier

surveys. These facts and relations are brought out in the following table:

Approximate area of phosphate lands, in square miles.

Year.	Recon- naissance surveys.	Detail surveys.	Total.	With- drawn.	Restored.
1908.....				7,000	75
1909.....	1,000	800	1,800	600	3,600
1910.....	1,400	500	1,900	65	90
1911.....	1,200	800	2,000	55	237
1912.....	400	400	800	1,800	465
	4,000	2,500	6,500	9,610	4,467

CLASSIFICATION OF PHOSPHATE LANDS.

FACTORS INVOLVED.

As the phosphate deposits on the public domain exist as stratiform sedimentary beds or as residual deposits of the placer type, they are, as a rule, readily found and their extent may be determined by ordinary methods of areal geologic mapping (pp. 50-61). In examining such deposits the geologic problems involved are chiefly structural. The purely economic considerations of accessibility, means of transportation, and nearness to market are highly important in the problem of establishing a commercial mine but are not involved in the classification of the land as phosphate or nonphosphate land.

The classification of a given tract as phosphate land is governed by the facts observed in the course of a field examination. A knowledge of the general geology of the region tells the examiner in what geologic environment the deposits may be expected, and a knowledge of the local succession of the beds tells him at what horizons and at what depths such deposits may be found in the tract examined. Before making a mineral or nonmineral classification of withdrawn phosphate lands it is essential to know exactly the distribution of the valuable deposits and to ascertain their relation to the legal subdivisions, so that the lands may be correctly described and classified. In making a classification it is also necessary to know the thickness and the number of the phosphate beds; the proportion of phosphoric acid (P_2O_5), or its equivalent expressed as tricalcium phosphate, that they contain; and the depths below the surface at which they occur.

The facts determined and recorded in the course of a field examination are shown on the township maps submitted by the field geologists to the land-classification board. If any of the data collected can not be represented on the maps they are supplied in the form of descriptive notes. One of the most essential factors to consider in the classi-

fication of any tract is the relation of the bed and its outcrop to that tract. If the rocks are in normal position—that is, if they have not been overturned or greatly disturbed by faulting—all the area underlain by rocks stratigraphically below the outcropping bed and therefore not underlain by the phosphate bed—may at once be classified as nonphosphate. In order to determine what lands are underlain by phosphate deposits it is necessary to work out from the recorded dips and strikes the structure of the field and to ascertain in what position and at what depth the phosphate beds lie. When these factors have been duly considered and the position of the phosphatic layer has been determined, it is necessary to know the regularity of the phosphate content of the bed, its variation in thickness, and the uniformity of its chemical composition from point to point in order to determine whether or not the tract contains a sufficient amount of phosphate to justify its classification as phosphate land.

Frequently in considering these factors it is desirable to make use of data of a confidential character which may have been procured in the course of the field examination. Such data, although used in determining the classification of the land, never appear on the map that is filed, but for all confidential sections, drill records, or other data only the location is indicated on the map and the material itself is kept separate from the general description and is not open to public inspection.

PRINCIPLES CONTROLLING THE CLASSIFICATION OF PHOSPHATE LAND.

Lands that have been included within phosphate reserves because preliminary examinations indicated that parts of them at least contain valuable deposits of phosphate whose exact distribution could not at that time be ascertained are further examined as soon as practicable and all lands barren of phosphate are recommended for restoration. In order to determine what lands should be so recommended and what lands should be retained in the phosphate reserve pending legislation providing for the disposition of phosphate deposits, it is necessary to determine what is and what is not to be regarded as phosphate land. It is very evident that lands which contain phosphate beds only an inch or two in thickness or with a content of tricalcium phosphate that is only 2 or 3 per cent of the entire mass or lands beneath which the phosphate beds lie at depths so great that they can not be commercially mined should be considered non-phosphate land.

REGULATIONS FOR THE CLASSIFICATION OF PHOSPHATE LANDS.

In order that the restorations and withdrawals may conform as nearly as possible to the factors that are involved in determining

whether a given bed of phosphate possesses any actual or prospective value as a source of commercial phosphate, the following regulations were framed and have been applied in the classification of phosphate lands.

The principles incorporated in these regulations are to be used primarily for guidance in determining what lands will be recommended for reservation and what lands will be restored or excluded from future reserves. These principles, however, are based on a careful consideration of the factors which affect phosphate values and which may be involved when provision has been made for the disposition of the phosphate lands or of the deposits themselves. Furthermore, due regard has been given to such future developments as can be anticipated from present conditions.

Phosphate deposits shall be classified according to their thickness, their depth below the surface, and their calculated tricalcium phosphate determined from phosphoric acid content.

Lands underlain by beds of phosphate less than 1 foot in thickness or containing less than 30 per cent tricalcium phosphate or lying at a depth greater than 5,000 feet below the surface shall be considered nonphosphate lands, except as hereinafter provided.

A. Lands underlain by beds of phosphate 6 feet or more in thickness and containing 70 per cent or more of calculated tricalcium phosphate shall be considered phosphate lands if the beds do not lie more than 5,000 feet below the surface. The depth limit for beds containing 70 per cent of calculated tricalcium phosphate shall vary from 0 to 5,000 feet in direct ratio to the variation of thickness of bed from 1 foot to 6 feet. For beds containing less than 70 per cent tricalcium phosphate the depth limit shall vary from zero to the depth of a 70 per cent bed of any given thickness in direct ratio to the variation in tricalcium phosphate content from 30 to 70 per cent.

B. Lands underlain at depths greater than the depth limit given in "A" by horizontal beds of phosphate 6 feet or more in thickness and containing 70 per cent or more of calculated tricalcium phosphate shall be considered phosphate lands to a distance of 10 miles from the outcrop or point of accessibility from which they can be reached by a horizontal tunnel, which distance shall be decreased to 0 in direct ratio as the thickness decreases to 1 foot. For beds containing less than 70 per cent calculated tricalcium phosphate the maximum distance for any given thickness of phosphate bed shall be decreased to zero in direct ratio as the percentage of tricalcium phosphate decreases from 70 to 30 per cent. If the phosphate beds dip toward the outcrop or lie above the point of accessibility, they shall be included under this paragraph.

C. The maximum horizontal distance for any given thickness of phosphate bed shall be decreased from that given in "B" to one-fourth that distance in direct ratio as the depth below the outcrop or point of accessibility increases from zero to the limiting value given in "A." This limiting horizontal distance applies both to horizontal and to dipping beds, but in no case shall land be classified as phosphate land where the bed lies at a depth below the point of accessibility greater than that given in "A" or where the amount of barren tunnel and shaft work required to reach the phosphate bed would be more than three-fourths of the total tunnel and shaft work required to mine the bed, 1 foot of lift being considered equivalent to 7.92 feet of haul.

D. Where the phosphate bed occurs at or near the surface so that the deposits may be readily mined by open-cut or stripping methods, the minimum thickness of a phosphate bed containing 70 per cent or more of tricalcium phosphate shall be 3 inches. For beds containing less than 70 per cent tricalcium phosphate the minimum thickness shall increase to 1 foot as the percentage of tricalcium phosphate decreases from 70 to 30 per cent.

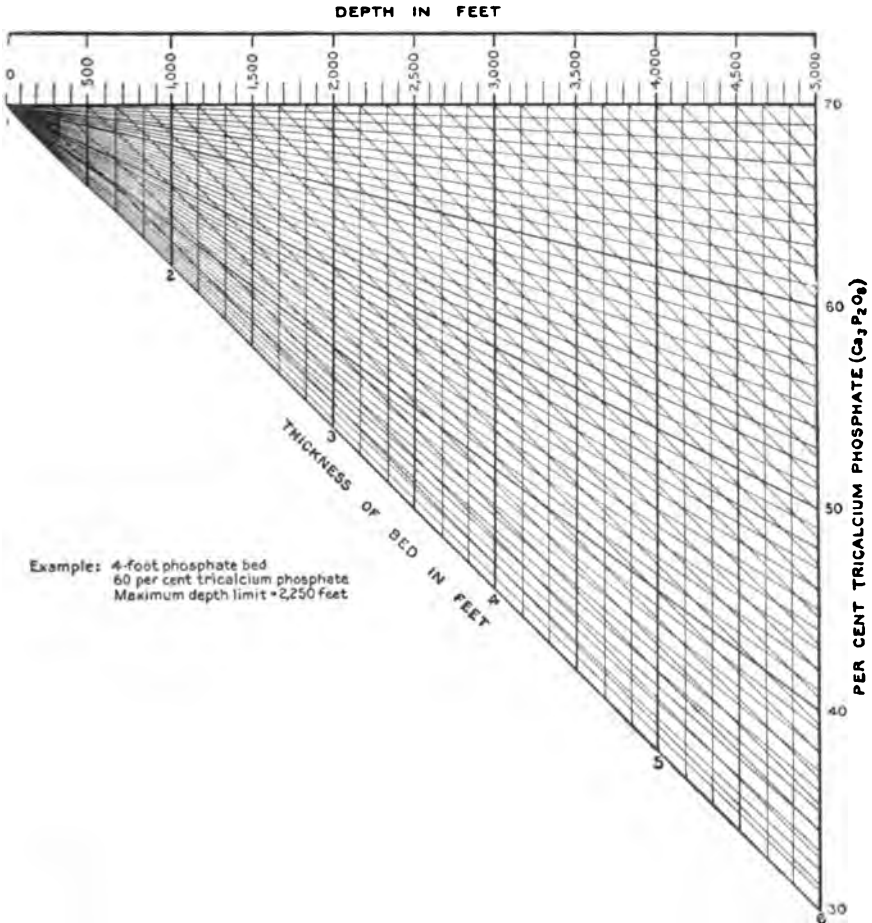


FIGURE 7.—Diagram showing depth to which phosphate deposits are classified under article A of the regulations.

PROGRESS IN CLASSIFICATION.

Classifications of the phosphate lands that have been examined are made according to articles A and D of the regulations. Recent field work in the closely folded phosphate region in the Western States and in the comparatively shallow deposits of Florida has shown that the attitude of the beds in these localities is such that it is not necessary to make use of articles B and C in classifying the lands. The classifications that are made according to the regula-

tions outlined in article D are comparatively simple, but those made under article A are much more complex and require considerable computation. In order to reduce to a minimum the computations involved in determining the maximum depth a given phosphate bed of known thickness and content of tricalcium phosphate may attain for the land to be classified as phosphate land, the accompanying diagram (fig. 7) has been constructed, by which each individual problem falling under article A can be readily solved.

All beds 6 feet or more in thickness are computed as 6-foot beds, and all beds having a content of tricalcium phosphate greater than 70 per cent are computed as 70 per cent beds. In order to determine from the diagram to what depth any phosphate bed whose thickness and content of tricalcium phosphate are known should be considered workable, the vertical line in the diagram that represents the thickness of the bed is selected and followed to its intersection with the diagonal line representing the percentage of tricalcium phosphate the bed contains. From this point of intersection the actual or constructed diagonal line is followed to the top of the diagram, where the maximum depth limit is given. Every 40-acre tract between the outcrop of the phosphate bed and the line where the bed reaches this depth limit should be classified as phosphate land.

Where the phosphate rock occurs in several thin beds or groups of beds sufficiently close together to be mined as a unit but with different percentages of phosphoric acid, all the material that can be mined as one bed should be taken, or in case part of it consists of barren rock that portion of the group that can be mined as a unit and will give the greatest amount of phosphate rock should be considered. Where more than one bed exists that can be mined separately without destroying the value of the other beds the land should be classified on the basis of each bed separately, all the lands being classified as phosphate land that can be so classified with reference to any one of the beds. This method of calculation gives the maximum amount of phosphate that can be obtained from the bed or group of beds and is the method used in determining what lands should be classified as phosphate land.

As a result of action of this type, based on field examinations made by the geologists of the geologic branch, withdrawals and restorations have been recommended from time to time.

Examples of withdrawal and restoration orders are given below:

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
Washington, January 25, 1913.

The honorable the SECRETARY OF THE INTERIOR.

SIR: Investigations by the Geological Survey in the Florida phosphate region indicate that the lands listed below lie within the phosphate area and prob-

ably contain valuable deposits of phosphate. These lands were reported by the General Land Office in a letter, dated January 15, 1913, as vacant Government lands, or as unapproved State or railroad selections. Their withdrawal is in accordance with the procedure outlined and advocated in my letter of August 16, 1912. I therefore recommend the submission to the President of the following order of withdrawal, involving 75,851 acres.

Very respectfully,

GEO. OTIS SMITH,
Director.

FEBRUARY 3, 1913.

Respectfully referred to the President with favorable recommendation.

WALTER L. FISHER,
Secretary.

ORDER OF WITHDRAWAL.

Phosphate reserve No. 16—Florida No. 5.

Under and pursuant to the provisions of the act of Congress approved June 25, 1910 (36 Stat., 847), entitled "An act to authorize the President of the United States to make withdrawals of public lands in certain cases," as amended by act of Congress approved August 24, 1912 (Public No. 316), it is hereby ordered that the following described lands be, and the same are hereby, withdrawn from settlement, location, sale, or entry and reserved for public use.

Tallahassee meridian.

T. 2 N., R. 1 E., sec. 6, E. $\frac{1}{4}$ of SW. $\frac{1}{4}$.

[Here follows the remainder of the land description.]

WM. H. TAFT,
President.

FEBRUARY 3, 1913.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
Washington, August 8, 1912.

The honorable the SECRETARY OF THE INTERIOR.

SIR: Field investigation by the Geological Survey indicates that the lands listed below do not contain deposits of phosphate. The following order of restoration, which involves 67,557 acres, is therefore recommended for submission to the President for appropriate action. Part of these lands are within coal withdrawals, but none are included in national forests, power-site or petroleum reserves.

Very respectfully,

GEO. OTIS SMITH,
Director.

AUGUST 17, 1912.

Respectfully referred to the President with favorable recommendation.

WALTER L. FISHER,
Secretary.

ORDER OF RESTORATION.

Phosphate restoration No. 6—Wyoming No. 2.

So much of the order of withdrawal made heretofore for classification and in aid of legislation affecting the use and disposition of phosphate lands, namely, reserve No. 4, as affects the lands hereinafter described is hereby revoked, for the reason that the Director of the Geological Survey reports that the lands are not valuable for the purpose for which withdrawn.

And it is further ordered that all such lands not otherwise reserved or withdrawn are hereby restored to the public domain and shall become subject to disposition under the laws applicable thereto upon such date and after such notice as may be determined upon by the Secretary of the Interior.

Sixth principal meridian.

T. 23 N., R. 119 W., secs. 5 to 7, inclusive;

sec. 18, all;

sec. 19, all;

sec. 30, all;

sec. 31, all.

[Here follows the remainder of the land description.]

WM. H. TAFT,
President.

AUGUST 17, 1912.

As a result of these orders, 3,291,527 acres of lands were included in phosphate reserves on January 1, 1913. The areas involved in these recommendations are indicated in the following table:

Phosphate land withdrawn, restored, and outstanding on January 1, 1913.

State.	Total with- drawals.	Restora- tions.	Outstand- ing with- drawals.
	<i>Acres.</i>	<i>Acres.</i>	<i>Acres.</i>
Florida.....	45,979	2,199	43,780
Idaho.....	2,215,834	1,157,778	1,058,056
Montana.....	274,861	.....	274,861
Utah.....	581,039	473,294	107,745
Wyoming.....	3,060,068	1,253,013	1,807,065
	6,177,811	2,686,284	3,291,527

LANDS BEARING POTASH AND RELATED SALINES.**GEOLOGIC OCCURRENCE OF THE DEPOSITS.**

No potash deposits of proved commercial value are yet known in the United States. Indeed, large deposits of potash salts are rare anywhere. Much the greater part of the world's supply is obtained from deposits in central Germany, first known from their discovery near Stassfurt. The only other noteworthy deposit in the world is said to be that at Kalusz, Galicia, in northern Austria. Deposits of the Stassfurt type may eventually be found in the United States, but

the chances are perhaps greater that potassium-rich saline deposits in this country will vary widely from the German type in the character of the salts and in their mutual associations. It appears, therefore, that a discussion of the geologic occurrence of potash based on the Stassfurt type alone would be inadequate if intended to apply to possible deposits in the United States.

Potash in its soluble or most useful forms is almost universally associated with other soluble salts. Therefore it is to the natural saline residues and natural or artificial brines and bitters that attention is directed in an exploration for soluble potash.

Great deposits of salines, especially those composed of sodium chloride or common salt, occur in many parts of the United States, but so far as known none of the important deposits now worked for salt contain an important percentage of potash salts. Saline beds occur at the surface in the arid regions of the West more abundantly than elsewhere. These occurrences include at least two types of deposits—the bedded salines included in stratified formations, which have commonly been tilted and otherwise displaced since their deposition, and the more recent saline deposits, which are to be found in the undrained playas and salt marshes of the Great Basin region.

The manner of formation of these more recent saline deposits is clearly revealed by the geologic record of the events that led to their accumulation and deposition. These events are so recent that the changes which are constantly taking place on the earth's surface have not yet obliterated or seriously obscured the evidence. This clearness and completeness of the geologic record justifies confidence in the correctness of the hypotheses concerning the manner of origin of saline deposits of this form.

Saline deposits in the Great Basin region, as elsewhere, are formed by the accumulation of the water-soluble constituents of the surface rocks of the earth's crust set free by that form of dissolution generally referred to as weathering. These salts thus freed are taken into solution by the rainfall and the ground waters and are gradually removed by the streams from the soils where they originate. Where these streams flow into inclosed basins with no outlet to the ocean, as is the rule in the Great Basin region, the dissolved salts are carried to the lowest part of the drainage area, where they accumulate. In the past, presumably because of greater precipitation than at present, these waters formed large lakes, which have since wholly or in part disappeared, and in the evaporation of these lake waters the salts have been deposited. Examples of saline deposits that have originated in this way in the low parts or so-called sinks of the inclosed drainage areas are common.

Saline deposits derived from the wash of continental areas normally contain among other constituents a certain proportion of

potash salts. As a whole, the quantity of potash associated with the sodium and other bases is so small—only 2 or 3 per cent of the whole—that the potash can not be recovered profitably for commercial use. However, as the potassium salts are somewhat more soluble than most of the other constituents of natural saline solutions, it is believed that they are generally among the last to be deposited when those solutions are evaporated. Owing to this selective action of evaporation it is probable that somewhere in the saline residues of completely desiccated lakes the potassium compounds will be segregated in much richer concentrations than elsewhere. This condition might not exist in natural saline deposits if the deposition of the salines were interrupted by some event which permitted the escape of the residual brines before all their constituents or final products were deposited. But apparently in the playas of the Great Basin no such event has interposed; hence all the constituents of the accumulated brines must still remain, and it is believed that in certain favorable places rich potassium-bearing salts exist.

Most of the lakes that formerly existed in the Great Basin have completely disappeared by evaporation. Vast quantities of saline residues must have been deposited by the final drying up of these lakes, but for the most part such deposits are not now seen at the surface. It is believed that the greater part of the salines deposited simultaneously with the disappearance of the lakes has since been buried by sediments carried into these basins by streams and deposited as alluvial wash or in later lakes that have occupied the original depressions. Older saline deposits elsewhere have been formed in a similar way.

If this hypothesis is sound, it follows that the probability of encountering saline deposits by drilling in the bottom of the desiccated lake basins is very great and that under favorable conditions potassium-rich salines will be among those encountered. It is hoped that such buried salines may not in all places be so deep as to be inaccessible.

Field work undertaken by the Government in the search for potash has heretofore been largely of an exploratory character and has not followed any general or established rule of procedure. A systematic study of brines, bitters, and rock-salt deposit in all parts of the United States is included in the general plan. The Geological Survey has drilled a well approximately 1,000 feet deep near the center of the Carson Desert, in northern Nevada. This test is not regarded as completed. Elsewhere in Nevada and in California a number of shallow drill holes have been sunk in other ancient lake basins. Some of these experiments are yielding significant and possibly important results.

CLASSIFICATION OF POTASH-BEARING LANDS.

Congress, responding to the urgent recommendation of the President, has so amended the withdrawal act (p. 43) that deposits of potassium-rich minerals may be included in reserves until an appropriate law for their disposition is enacted. In view of the variety of such deposits in commercially available form and of their importance in industry, it is doubtless the intention of Congress, if the present search is successful, to make appropriate provision for their development and disposal. Meanwhile, as investigation by the scientists of the Government bureaus reveals promising localities, these localities, if they involve public lands, will be withdrawn from entry until their value as sources of potash can be demonstrated or disproved. If they prove to contain rich deposits the withdrawals will be maintained until Congress can act. Three reserves of this type have already been created by the President. They include 133,829 acres in Nevada and California.

The order of withdrawal by which potash reserve No. 2 was created is given herewith as an example of this type of action.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
Washington, February 20, 1913.

The honorable the SECRETARY OF THE INTERIOR.

SIR: Investigations by the Geological Survey in the State of California indicate that the lands listed below, which lie within a dry lake known as Searles Lake, probably contain valuable deposits of potash. I therefore recommend the submission to the President of the following order of withdrawal, which involves 69,840 acres.

Very respectfully,

GEO. OTIS SMITH,
Director.

FEBRUARY 20, 1913.

Respectfully referred to the President with favorable recommendation.

WALTER L. FISHER,
Secretary.

ORDER OF WITHDRAWAL.

Potash reserve No. 2—California No. 1.

Under and pursuant to the provisions of the act of Congress approved June 25, 1910 (36 Stat., 847), entitled "An act to authorize the President of the United States to make withdrawals of public lands in certain cases," as amended by act of Congress approved August 24, 1912 (Public No. 316), it is hereby ordered that the following described lands be, and the same are hereby, withdrawn from settlement, location, sale, or entry and reserved for classification and in aid of legislation affecting nonmetalliferous mineral deposits:

Mount Diablo meridian, California.

T. 24 S., R. 43 E., sec. 32, SE. $\frac{1}{4}$ of SE $\frac{1}{4}$;
sec. 33, S. $\frac{1}{4}$;
sec. 34, SW. $\frac{1}{4}$, W. $\frac{1}{4}$ of SE. $\frac{1}{4}$, SE. $\frac{1}{4}$ of SE. $\frac{1}{4}$;
sec. 35, S. $\frac{1}{4}$ of SW. $\frac{1}{4}$.

An area bounded as follows: Beginning at the southeast corner of sec. 31, T. 24 S., R. 43 E.; thence west 2 miles; thence south 12 miles; thence east 9 miles; thence north 12 miles; thence west $2\frac{1}{2}$ miles, more or less, to the south quarter corner of sec. 36, T. 24 S., R. 43 E.; thence west $4\frac{1}{2}$ miles, more or less, along the south line of T. 24 S., R. 43 E., to point of beginning.

This withdrawal is made subject to all rights lawfully initiated under any valid mining locations made upon said lands so long as such rights are maintained in full compliance with law.

FEBRUARY 21, 1913.

WM. H. TAFT,
President.

As the geologic conditions under which potassium deposits are formed differ from those required for the deposition of the other nonmetalliferous minerals, except the related salines, special field methods have been used for their discovery. The steps to be taken in classifying lands as potash-bearing or potash-free subsequent to field examination are, however, identical with those followed in the classification of lands with regard to such other resources as phosphate and petroleum. The present laws do not provide for appraisal and sale, as in the case of coal lands, nor for lease.

MISCELLANEOUS NONMETALLIFEROUS MINERAL LANDS.

Some of the important minerals besides those already discussed are limestone, building and ornamental stones, cement materials, slates, glass sand, gravel, volcanic ash, diatomaceous earth, kaolin and other clays, fuller's earth, gypsum, borax, salt, sulphur, monazite, talc, soapstone, quartz, feldspar, cryolite, mica, gems and precious stones, strontium compounds, fluor spar, barytes, pyrite, graphite, asbestos, magnesite, abrasives, asphalt and other hydrocarbons such as gilsonite and ozokerite, mineral waters, mineral paints, and bromine, as well as guano and peat.

A great many of the so-called nonmetalliferous minerals contain metallic elements which either can not be extracted commercially or are regarded as of little or no value as metals but which by their union with nonmetallic elements form substances that are sought because of their nonmetallic properties. This is true of such minerals as corundum, an oxide of the metal aluminum, and gypsum, a sulphate of the metal calcium. Monazite is sought as the chief source of oxides of several rare metals. There are, however, so-called nonmetalliferous minerals whose metallic content is high and which may under certain conditions be regarded also as metallic minerals. A notable example is pyrite, a sulphide of iron, which is extensively employed in the manufacture of sulphuric acid because of its high content of sulphur. With advancement in industrial chemistry some minerals now classed as nonmetalliferous may be placed in the category of those which yield valuable metals and others now used may be discarded.

The geologic occurrence of the minerals named in the foregoing list is very diverse and the characteristics of the deposits containing them will therefore be referred to but briefly. Many of them exist in stratified or bedded form. Limestone, building stones, some cement materials, and some ornamental stones occur as sedimentary or metamorphic rocks. Slates are obtained usually from beds and are quarried in much the same manner as other kinds of building stone. Glass sand is made by crushing a loosely consolidated sandstone or is obtained from beds of loose sand. Gravel is usually found in more or less bedded form in so-called "gravel banks." Volcanic ash and diatomaceous earth are ordinarily found in stratified deposits or beds. Clays, including kaolin and fuller's earth, result from the accumulation of the less soluble residues of the decomposition of pre-existing rocks and minerals and are obtained almost entirely from bedded deposits. Some clays are obtained by dredging the bottoms of streams or lakes. Kaolin in its purest form results from the decomposition of pegmatitic feldspar in place.

Gypsum, borax, and halite, or common salt, are found in deposits that are related with respect to the manner of their geologic occurrence. They are found most abundantly in association with stratified rocks and are regarded as chemical deposits resulting from the evaporation of waters of inland seas and lakes. Some deposits of borax and halite occur in more or less stratified form in the beds of present-day salt lakes or marshes. Sulphur deposits large enough to be of economic importance occur as products of volcanic activity and are found near volcanic craters and also near some hot springs, either active or extinct.

Monazite, owing to its minute crystalline form and great weight, occurs in greatest quantity where it has been concentrated in placer deposits.

Talc and soapstone are very soft minerals which have presumably resulted from the alteration of other minerals. Soapstone, a talc schist, occurs with other rocks of various kinds, usually crystalline or metamorphic; talc occurs in beds intercalated in schistose limestone and in lenses or pockets in certain intrusive rocks.

Many minerals exist in veins or in the form of lode deposits. Quartz, feldspar, cryolite, mica, and some gems are found in veins in crystalline rocks. The strontium minerals occur principally in lenses, in granular and columnar masses, in bedded deposits, and in crystals that form nests and geodes in limestone. Fluorspar is found, as a rule, in veins in limestone, gneiss, schist, and sandstone. It is a common gangue of metallic ores, particularly those of lead, zinc, and tin. Barytes occurs in veins and beds associated with other ores, as well as in veins and masses in limestone.

Pyrite is found in fissure veins and along the bedding planes of sedimentary and metamorphic rocks. It occurs in various other forms in rocks of practically all kinds and ages. Graphite is found mainly in the older crystalline metamorphic rocks in embedded masses and veins, although in some places it occurs in beds.

Asbestos is an alteration product found in veins in older crystalline rocks. Magnesite is also generally regarded as an alteration product and is found in veins as well as in bedlike masses. Some abrasives, like corundum, emery, and garnet, occur in small crystals, principally in veins in igneous and metamorphic rocks.

Some asphalt impregnates sands, sandstones, and limestones and occurs in veins in these rocks. Other hydrocarbons, such as gilsonite and ozokerite, are found in veins or fissures, usually in sandstones or shales.

Mineral waters are, of course, obtained from springs; and some common salt and sulphur, as well as the materials of some mineral paints, are obtained from deposits formed by the evaporation of spring water. Bromine is found in natural brines and bitterns.

Guano occurs in massive deposits, which in some regions are of considerable thickness. It is usually found in caves or other protected places. Peat results from the accumulation in bogs of plant remains that have undergone slight modification at the top, although if the deposit is thick its lower portion may have been reduced to a mass somewhat resembling lignite.

Sections 2320 to 2325, inclusive, of the Revised Statutes prescribe certain rules and regulations to govern the location and patenting of "mining claims upon veins or lodes of quartz or other rock in place bearing gold, silver, cinnabar, lead, tin, copper, or other valuable deposits." Section 2329 provides for "claims usually called 'placers,' including all forms of deposit, excepting veins of quartz or other rock in place." Thus, although the minerals in the foregoing list exist in nature in beds, in veins, in massive form, or as liquids, or even in more than one of these forms, the law divides them into only two great classes—those which occur in veins or lodes of quartz or other rock in place and those usually called placers, including all other forms of deposits. The distinctions as to mode of occurrence of these minerals in nature are considered in classifying as mineral or nonmineral the lands containing them; such distinctions are the primary factors that under the present mining laws must be considered in determining the law under which the deposits may be acquired.

A large part of the information heretofore obtained by the Geological Survey regarding these minerals has been gathered in reconnaissance examinations and in connection with reports on mineral resources, with the result that in most of the areas examined much geologic information that would be necessary for land classification

has not been obtained, although the data gathered are entirely adequate for the purposes for which they have been sought.

No particular method is at present followed in the field examination of deposits of these minerals, and there is no necessity for methods materially different from those pursued in detailed work on other metalliferous or nonmetalliferous deposits. Nor do the requirements as to the data to be gathered and the form in which they should be assembled differ essentially from those for other minerals. In addition to the location, a brief description of the nature and geologic structure of the rocks in which the deposits occur, with data regarding the thickness and succession of the rocks, their dip and strike, the extent of the deposits, and analyses of the material, are all important in the examination of bedded deposits. In the consideration of vein deposits data regarding the character of the vein, the systems and directions of joints, fissures, and fractures which may have formed the ore cavities, the dip and strike of the veins, the nature of the gangue material, and the wall rock are equally important. Statements of production are always desirable. The question of relative value—that is, of mineral value as compared with agricultural, power, or other values—must be considered in the classification of some lands because of the fact that the laws governing the disposition of certain minerals refer specifically to lands that are “chiefly valuable” therefor. Other factors, some or all of which are in many cases to be considered in judging the relative value of a mineral deposit, are the following:

1. Demand for the mineral, both present and future.
2. Character of the deposit; chemical and physical properties and extent.
3. Location with reference to market and in some cases to fuel supply.
4. Transportation facilities and rates.
5. Market price of the product.
6. Whether or not the particular deposit possesses other peculiar advantages rendering it more valuable than like deposits in the region and elsewhere.

The character of the deposits, their location, and the transportation facilities influence the cost of production by their effect on the cost of working the deposits, the cost of the plant, and in some places the cost of the fuel used in the manufacture of the product. These factors may also exert a most important influence on the selling price of the output by their effect on the cost of placing it in the market.

If the earlier geologic examinations had been made with a view to classification more precise instrumental work and a record of all the factors outlined as having a bearing on the deposits would have been required. No attempt has yet been made to systemize for purposes of land classification the available data regarding these minerals, and although the Geological Survey has prepared and sub-

mitted to the General Land Office many reports that have been a guide to action by that office and have been equivalent in many cases to nonmineral classification and in a few cases to mineral classification, no withdrawals and no formal classifications of lands because of their content of any of these minerals have been made. Although such minerals are useful and valuable, they are not in general of so great present or prospective use or value as coal and certain other nonmetalliferous minerals contained in lands for whose classification more specific provision has been made. Practically all minerals are of some value, but those of greatest value are naturally those which have the greatest present or future use and which are at the same time most easily or profitably marketable. Sand, for example, is of great use, but it is so common that in most localities it has almost no market value. Therefore, although the lands containing the nonmetalliferous minerals here discussed are, at the discretion of the President, subject to withdrawal and classification under the act of June 25, 1910, as amended by the act of August 24, 1912, there is no such public need for segregating these lands as there is for segregating lands containing deposits of such minerals as coal, oil, potash, and phosphate. Nevertheless, should it be deemed by the President to be in the public interest to withdraw or to classify as mineral land an area containing any of these deposits, because of a public need for a present or a future reserve supply, or with a view to preventing alienation of the mineral deposits under laws relating to nonmineral land, or as an aid to future disposition, his action would be based on a question of fact which it is the province of the Geological Survey to determine. So long as such withdrawal or classification is not deemed to be in the public interest, however, the land will remain open to exploration, discovery, occupation, and purchase under the mining laws unless Congress shall otherwise provide.

METALLIFEROUS MINERAL LANDS.

PURPOSE OF CLASSIFICATION.

The usual object in view in a consideration of the classification of nonmetalliferous lands as mineral land is to obtain their temporary withdrawal from entry, either to permit their appraisal, as in the case of coal land, or to await protective legislation, as in the case of potash or phosphate land. But metalliferous lands, as such, are not subject to withdrawal, and their classification is directed to other objects, which will be indicated by a brief account of some cases that have been considered by the Geological Survey.

Perhaps the most important case yet considered is that relating to the Northern Pacific land grant. Every alternate section in a strip extending 40 miles on each side of the right of way was granted to the Northern Pacific Railroad Co. to assist it in constructing a trans-continental line, but the act provided that the railroad company should not receive any lands that were valuable by reason of their content of mineral deposits other than coal and iron. It therefore became necessary to classify the entire grant with respect to its value for such deposits, and in practice the chief problem of this classification has been to determine the presence or absence of valuable metalliferous deposits. A great part of this classification was accomplished by specially appointed commissioners, and the Geological Survey had no part in the work until 1905. In that year a Survey geologist, accompanied by a field agent of the Land Office, examined a large portion of the grant lying in Idaho and Montana in order to obtain information supplementary to that on which the special commissioners had recommended a mineral classification of the greater part of this tract. The Survey, however, took no further action regarding that particular examination. The greater part of the tract was classified as mineral land as the result of a hearing before the register and receiver at Coeur d'Alene, Idaho, but this classification was set aside by the Commissioner of the General Land Office on petition of the Northern Pacific Railway, on the ground that it was based on insufficient field work. In 1910, therefore, an appropriation was made by Congress (act of June 25, 1910; 36 Stat., 703, 739) for a new and much more thorough examination, for making which the Commissioner of the General Land Office requested the services of members of the Geological Survey. Four parties, each comprising a geologist, a geologic assistant, and the necessary camp hands, devoted the field season of 1910 to the work, which was completed in the season of 1911 by three similar parties. The resulting classification, however, was not sufficient to decide the status of all the lands in controversy. The railway company had the right to contest classifications adverse to its interests and exercised this right as to many of the lands which, because they were classified as mineral, would be excluded from the railroad grant. Hearings on the contested classifications are held before the registers and receivers of the appropriate land districts. An appeal can be taken from the decision of these officers to the Commissioner, and from him to the Secretary. No final decision has yet (February 28, 1913) been rendered concerning any of the classifications of the Survey that are under contest.

The Survey has also been required to classify several Indian reservations, in whole or in part, either before or after the reservations were opened to settlement, the question in the one case being

whether or not the lands shall be allotted to the Indians, in the other what kind of entry or settlement on them shall be permitted. Lands valuable for minerals are withheld from allotment to Indians, as they are from the Northern Pacific Railroad grant, although for Indian lands no exception of coal and iron is made. A Survey geologist was engaged during the summer of 1912 in classifying the Flathead Reservation in Montana for the purpose of determining the mineral character of certain lands and their availability for allotment to the Indians, and many other classifications, both of individual allotments and of entire reservations, have been reported to the Indian Office.

Before Indian lands are thrown open to settlement it is desirable to know what parts of them contain valuable mineral deposits, in order that these parts may not be alienated as agricultural land. Failure to classify the lands in advance of the opening of the reservations is likely to result in conflict between agricultural and mineral claimants. This has occurred, for example, in the northern part of the Colville Reservation, which was thrown open to prospectors in 1898 and to agricultural claimants later. Numerous protests made by mineral claimants in this region against the issuance of patents to agricultural claimants have aroused the bitter resentment of the ranchers, who have been prevented by these protests from getting final patents. An examination of these lands for the purpose of determining whether the mineral claims showed deposits sufficiently valuable to entitle the claimants to mineral patents or whether these claimants were acting in bad faith, as alleged by some of the ranchers, was accordingly made by a geologist of the Survey in the season of 1912; and during the same season the unallotted part of the Colville Reservation was examined for the purpose of settling conflicts between mineral claimants and Indian allottees and of classifying the remaining unallotted lands.

Another type of classification has arisen of late, in which the Survey has been required to pass upon many and varied individual cases in which the propriety of granting patent to claimants was in doubt. It is sometimes suspected that attempt is being made to obtain valuable agricultural or timber land or strategic points for power development by the subterfuge of a mining claim on land where in reality no mineral deposit of substantial value has been found. On the other hand, there is sometimes danger lest a valuable lode or placer deposit be covered by some form of nonmineral entry. If these cases are important the department may call upon the Survey for any information that it may possess concerning a certain tract, or it may even direct that a geologist be detailed to make a special examination. One case of this type, of interest as one of the earliest examples of land classification by the Geological

Survey, was the determination of the nonmineral character of a "school section" on the edge of the city of Tacoma, Wash. This detailed examination was made in 1895 and resulted in the defeat of the mineral claimant, who had attempted to obtain under the placer law nonmineral land possessing large suburban value. As a result of the decision the title to this land passed to the State of Washington.

METHODS OF CLASSIFICATION.

AGENCIES EMPLOYED.

Classifications promulgated by the Survey are made by the metalliferous section of the land-classification board and are based on data gathered by the field geologist and by him presented to the section. Other geologists having special knowledge of the area or type of deposits under consideration may be called in, so that each classification represents the best scientific and technical judgment of the Survey.

PROBLEMS INVOLVED.

Each classification of metalliferous land involves one or both of the following problems: (1) Whether an alleged "discovery" of mineral constitutes valid ground for issuing a mining patent; (2) whether certain lands are without value for their metalliferous minerals and may therefore be patented under the laws relating to nonmineral land. The first problem is typically presented where the propriety of issuing patent to a mineral claimant is in question; a typical example of the second problem is that presented by the Northern Pacific land grant.

Evidently the first problem is the more concrete and the more readily solved. In order to determine the validity of a specific mineral claim all that is necessary may be to find and identify the claim and to estimate the value of the lode by sampling. The most difficult cases, on the other hand, are probably those that involve the classification of large areas in which little prospecting has been done. In order to reach an intelligent conclusion in such a case evidence of many kinds must be obtained, the gathering and effective presentation of which may involve the making of a fairly complete topographic and geologic map, a task which only a geologist can effectively perform.

In actual practice few cases present only one of the problems stated. Even if the main problem is the first one it is usually desirable that the examiner should learn something of the general geology of the district; and if, on the other hand, the main problem is the second the apparent value of particular claims is an important part of the evidence. It is not necessary or practicable, therefore, to separate

the two main groups of cases in the detailed account of field methods that follows, despite their clearly distinct legal status. In most of the cases considered nearly all the kinds of information to be enumerated are used to a greater or less extent, and a geologic map of some kind invariably forms a part of the record.

The metalliferous deposits examined or looked for in most of the investigations preceding classification are veins, magmatic ore bodies, contact-metamorphic deposits, and bodies formed by replacement. In mining law these deposits are usually comprised in the term "lodes," and they may conveniently be so designated here. Some cases have to do with placer deposits, which are easier to examine and classify than lodes.

PRELIMINARY PROCEDURE

As in the classification of nonmetalliferous lands and geologic field work in general, it is the duty of the geologist, before he takes the field, to gather information about the geology of the region to be examined and to provide himself with a base map. Other information that is especially desirable for work of this class relates to the location and status of the mining claims in the region. This is the only matter that requires further notice here, for the subject of base maps has been discussed elsewhere (pp. 53-60) and the utility of geologic information is self-evident.

Plats and descriptions of patented mining claims are on file in the offices of the surveyors general of the several States and in the General Land Office at Washington. These show accurately the position of the claims with reference to land lines or location monuments. Provided with copies of these records, the examiner is able readily to find the patented claims. Less complete and accurate descriptions of the unpatented claims are filed in the offices of county clerks with the first records of location and the affidavits on assessment work.

FIELD WORK

LOCATION AND TOPOGRAPHY.

The methods of location used in classification of this kind may be any of those described on pages 53-61. Some of the conditions of classifying metalliferous land, however, influence the selection of methods. The minute accuracy that characterizes much of the work on coal land is not often necessary in work on metalliferous deposits, and it is therefore feasible to use comparatively rough methods like that of the pacing traverse, which has been employed to a considerable extent. Another influential fact is that metalliferous land is more likely than nonmetalliferous land to be situated in mountainous territory. This is not obvious at first glance, but as metalliferous

deposits are most common where the geologic structure is complex, and as mountains are regions of upheaval and disturbance, the connection between topography and mineral wealth is real. The ruggedness of the areas in which the greater part of the work of classifying metalliferous land is done precludes the use of some methods that are especially adapted to work in a flat country, such as that in which distance is measured by the paces of a horse. The plane table is much used in open country, and stadia traverses of roads or streams are sometimes made for purposes of control.

INVESTIGATION OF PLACER DEPOSITS.

Geologic relations.—Although theory is not so important in relation to placer deposits as in relation to lodes, the physiographic history of the region may afford some guidance in the search for valuable placer ground, as the following considerations will show.

The most important geologic principle relating to placers is that concentration sufficient to make a valuable deposit has usually been the result of long and perhaps repeated working over of the gravels by streams. Therefore, other things being equal, well-washed deposits consisting in part of reworked older gravels would seem most likely to be rich in gold. Moraines, on the other hand, or glacio-fluvial deposits close to the place of their origin are unlikely to contain gold in sufficient concentration to be extracted with profit.

With respect to the distance of the gravels from their source, however, a happy medium is favorable. Too great proximity is inconsistent with efficient concentration, but the gold, except in extremely fine division, is not carried so far as the gravels, and too great remoteness from the source is therefore also unfavorable. Gold-bearing placers are likely to show a definite relation to such areas of auriferous bedrock as can be outlined; they are partly within those areas but extend beyond their borders as a sort of fringe.

Testing.—Although a knowledge of the general geology and physiography of the region may be a guide in the search for placers, the classification of land as valuable placer ground is always supported by more direct evidence, for the reason that the extent and value of a placer deposit can be determined much more closely than those of a lode. The examiner is expected to pan the gravels of all important streams in the area classified in order to obtain evidence regarding their possible value as placers and, incidentally, evidence regarding the gold content of the bedrock from which the placers have been derived.

Testimony of miners.—Owing to their necessary limitations, the tests made by the examiner must be supplemented as fully as possible by the testimony of miners and prospectors. From these the ex-

aminer may learn the tenor of the gravels, the probable extent of the pay dirt, and whether mining has been profitable. This testimony may be taken under oath, if the examiner has power to administer it, and should be corroborated, so far as possible, by assay certificates and other evidence. A geologist is able also to criticize the testimony in the light of geologic facts and would perceive, for instance, that an assertion that morainal gravels had been worked with profit would be in especial need of corroboration.

INVESTIGATION OF LODE DEPOSITS.

Kinds of evidence available.—The evidence which must determine whether land is to be classified as mineral because of lode deposits may be subdivided as follows: (1) General geology; (2) occurrence of valuable minerals or gangue minerals, disseminated or in veins, found in outcrops or float; (3) prospects and mines; (4) assays; (5) history of the region. Evidence of the first two classes is especially important in regions that have not been thoroughly prospected.

General geology.—Certain geologic conditions, such as fissuring of the rocks, are generally recognized as favorable to the deposition of ore bodies; others, such as lack of deformation and very young country rock, are unfavorable. But ore deposits are the result of a happy combination of several factors, and it may be difficult to consider these factors separately and determine their relative weight. Of two districts geologically similar, one may be rich and the other poor in ore deposits, because of some difference not readily perceived. The most general cause of such differences, perhaps, is the variation in what Chamberlin and Salisbury call the "diffuse regional concentration" of the several metals, whether in sediments or magmas, which is presumably the cause of metallogenic provinces.

Now, it is evident that geologic conditions, including obscure conditions that may be largely determinative, are more likely to be similar in neighboring than in widely separated areas. Neighboring districts are the more likely, for one thing, to be in the same metallogenic province. Therefore, in judging whether a given geologic condition is favorable or not, the investigator should especially inquire whether it seems to favor the deposition of ores in the vicinity of the area to be classified. For example, if ore bodies are known in one locality at the contact of a batholithic intrusion with a certain limestone formation, it is probable that they will be found at the contact of the same rocks in neighboring localities.

This reasoning by analogy may form one of the arguments in support of a mineral classification, but it can rarely be made the sole ground for such classification of a large area, which can hardly be successfully defended against a contest unless it is supported by some definite discoveries of mineral, made by prospectors or by the geolo-

gist himself. In fact, such concrete occurrences of mineral are likely to have even more weight in a contest than strictly geologic evidence. It may pertinently be asked, then, what special qualification for gathering the evidence required is possessed by a geologist compared with a prospector or any other intelligent observer.

The geologist would perhaps have no special advantage if unlimited time were allowed for the examination. In fact, however, the time is limited, it may be all too strictly. It is impossible within the time allowed to explore every square foot of the area, and therefore observation must be concentrated where deposits are most likely to be found. Now, in determining what places are best worth examination the geologist finds abundant practical use for his knowledge both of general and of local geology. His general knowledge teaches him that some geologic conditions are more favorable than others to the formation of valuable deposits, and he distributes his attention accordingly. He does not, for example, waste his time in looking for quartz veins in undisturbed rocks, knowing as he does that deformation and fissuring are necessary to the formation of veins. The special knowledge of the region which he may already have or which he is prepared by training to assimilate rapidly will enable him to recognize in the geologic environment of the ore deposits that have been found the details that are significant. If, for example, most of the known deposits of a district are the result of interaction between a limestone and an igneous intrusive, the geologist will presumably be quicker than a layman to recognize this fact and will explore with especial care the contacts between these rocks in areas near those which have proved productive. The geologist, in short, is better prepared than the layman to follow clues.

The shorter the time allowed for the examination the more decided the advantage of the geologist over the man without geologic training. An exploration sufficiently thorough to discover even a large proportion of the valuable deposits in the region to be classified is rarely possible, and the value of many of the deposits found must be doubtful before they are thoroughly explored. It is correspondingly important, then, that the fullest and most reliable inferences be drawn from the data obtained in the field.

The following paragraphs are intended to show what kind of geologic evidence the examiner seeks.

Country rock.—The broadest generalizations that can be made regarding the influence of country rock, as indeed regarding other geologic factors, are of negative character. It is safe to say that very young unaltered volcanic rocks or imperfectly consolidated sediments are unlikely to contain metalliferous lodes. Further than this, however, the probable richness of a formation bears no direct relation to

its age, for valuable deposits are found in rocks of all ages, from the Tertiary to the most remote.

In a particular district, however, the ores may show a preference for certain rocks. The favorable rocks may be those that contain minerals in a finely disseminated condition which may be valuable if they are anywhere sufficiently concentrated. Copper, for example, seems to be a constituent of some basic igneous rocks. Ready replaceability, or the power of reacting vigorously with mineralizing solutions, may be the determining favorable factor; and where the typical deposits of a district are replacements or contact-metamorphic deposits calcareous sediments are usually more favorable than others. Again, the presence of some constituent which acts as a precipitant may determine the concentration of a valuable mineral; organic matter probably precipitates gold under some conditions, and carbonaceous slates appear to be a common country rock of gold deposits. Finally, some purely physical feature may be determinative. The hard rocks of a district may be fissured to form breccias in which the ore-bearing solutions can circulate and deposit, while fissures in soft rocks would be clogged with impermeable gouge; and fissures which are large and persistent in massive rocks might ramify, on entering fissile rocks, into a multitude of small slips parallel to the bedding or cleavage.

Intrusions and metamorphism.—Although the nature and degree of the relation between igneous intrusion and ore deposition are still moot points, it is an established fact that ore deposits are especially abundant in the vicinity of intrusive contacts. Apart from stratiform deposits—such, for example, as those of iron oxide—ore bodies so remote from intrusive rocks as the lead and zinc deposits of the Mississippi Basin are rather exceptional, though not so exceptional as to make absence of intrusives a sufficient ground for classification of land as nonmineral. The general similarity in the distribution of ore deposits and of igneous rocks is particularly notable in the Western States. The presence of igneous intrusions must therefore be considered favorable, in general, to the deposition of ores.

Ore bodies related to intrusion are found both in the intrusive rock itself and in the surrounding sedimentary rocks. Those which are not contact-metamorphic deposits in the strict sense are not more likely to be at the immediate contact than at a considerable distance from it. The central portion of a very large batholith is likely to be barren, but the peripheral portion is commonly ore bearing, and all of the denuded portion of a small batholith or stock is likely to contain ore deposits, for none of it is far from the contact. Large dikes also form the country rock of many ore deposits. The ores are formed in the rocks cut by the intrusive, not only within but beyond the zone of contact metamorphism.

Structure.—The geologic structure of most mining districts is complex, and in regions of nearly horizontal unfaulted strata metalliferous lodes are scarce. Deformation, by giving rise to fault fissures and openings along bedding planes, probably determines the location of most lodes and is therefore favorable, in general, to the deposition of metalliferous ores.

Faulting is of greater importance in the formation of lodes than folding. Some faulting is doubtless a prerequisite to the formation of fissures transverse to the bedding, although fault fissures along which great displacement has been effected are not commonly filled with veins of commercial importance, for, inasmuch as they are likely to be choked with gouge and subject to repeated movement, they are less likely to be ore bearing than fissures along which the displacement has been slight or even imperceptible. Veins are accordingly looked for near and parallel to faults of large throw rather than along those faults themselves. That sort of faulting which gives rise to a rather coarse breccia is perhaps most favorable. At any rate, zones of brecciation afford the best clue for the tracing of small faults and are likely to be mineralized. They are therefore looked for and examined with especial care.

Folding, as well as faulting, may give rise to openings in which ores may be deposited. Saddle reefs constitute the most common type of deposits in openings thus formed.

Outcrops and float of lodes.—Outcrops of lodes afford the most direct evidence of mineral value that can be observed in the field apart from actual development, and they are therefore located and described with as great care as is practicable. If the deposits are veins, the direction and degree of persistence are determined if possible; this determination is particularly important if the classification must be close in the matter of location, but it is also important if in a neighboring region veins of a certain direction are known to be especially rich. Size and composition are other features noted. Size affects, of course, the degree of value, but the mineral content is of more immediate interest to the examiner.

In order to recognize lodes of probable value, the examiner endeavors to learn as much as possible concerning the appearance of the outcrops of lodes containing valuable minerals and familiarizes himself with the minerals likely to occur in the extremely oxidized portions of such lodes. Details regarding the surface indications along veins of proved importance in the region examined are sometimes obtained from prospectors and miners. The importance of these indications may be very great, for the minerals that make the lode valuable may not appear at the surface. More commonly than not the primary sulphides are represented at the surface by oxides or carbonates. The thoroughly weathered portion of a rich lode may even contain no

compounds of the valuable metals. This is especially likely to be true of copper deposits, whose upper portions are commonly transformed to rusty porous masses containing quartz, iron oxide, and other substances that resist the action of the weather. This material, which is known as iron capping or gossan, may contain small amounts of the bright blue and green copper carbonates, but on the other hand it may be wholly devoid of copper minerals. Many lodes that weather to a gossan and others that are composed largely of easily weathered minerals do not project above the surface and are therefore likely to be overlooked. If a lode is about as hard as the country rock its outcrop is nearly level with the general surface, and the position of a lode composed of soft, easily weathered material may be marked by a trench instead of a ridge. Many veins, again, have no outcrop; they are covered with soil, and their position is indicated only by float. It is therefore evident that both careful observation and intelligent inference are required to find the lodes and judge whether or not they are likely to prove valuable.

The proximity of lodes containing minerals in sufficient concentration to be commercially valuable may be indicated by the presence of such minerals or of gangue minerals associated with them, disseminated through the country rock or in the form of narrow stringers. Some minerals commonly so found are calcite, pyrite, siderite, and chalcopyrite. The more easily weathered minerals are likely to be represented by their oxidation products. Siderite, for example, is usually and pyrite commonly represented by pseudomorphs of hydrated ferric oxide. Extensive rusty staining of the country rock therefore causes the examiner to look for more specific evidence of mineralization. Other characteristic alterations of the country rock, such as leaching, chloritization, and sericitization, commonly occur along the walls of lodes and are therefore useful as clues.

Probably the great majority of prospectors' discoveries are made by following float¹ to its source, and mineral classification likewise may rest in large measure upon the evidence afforded by float. Time will not always permit the tracing of float to its source, and the examiner must then be content with inferences drawn from the character and situation of the float as he finds it. In any case the first step is to consider how the float probably reached its actual position. It may have done so by either (1) hill creep, (2) water transportation, or (3) ice transportation, or by a combination of any of these agencies.

1. Most float has been transported to its present position by hill creep, which is constantly active on every slope. Angular float, without marks of attrition, which does not lie in an actual or former stream

¹ This term is commonly applied by prospectors to all fragments of lode matter not in place, however transported; it will be used in this sense here.

channel or in a glaciated area has presumably come to its place by hill creep, and its source should be looked for, after the method of prospectors, by following it straight uphill. Normally the parent lode will be found somewhere between the point where the float was discovered and the top of the slope. If a search is impracticable the probable source may perhaps be inferred, on the same principle, within narrow limits, especially if a good topographic map is available; the source may thus be assigned to a particular section or even to a smaller subdivision. Moreover, the probable source can often be judged within narrower limits than those set by the distance from the point of discovery and the top of the slope. The small fragments of vein quartz, mingled with soil, which may be found almost anywhere in a region of deformed rocks, are likely to have crept downhill for a long distance; but large blocks of quartz thickly strewn over a small and fairly well defined area, especially an elongated area on a moderate slope, may reasonably be presumed to have come but a short distance from a vein. It is evidently necessary, then, to note fully, on the spot, the size and character of the float fragments as a help in judging the source; and their size may also roughly indicate the thickness of the parent lode.

2. Rounded fragments or boulders of float, especially if in a stream channel in an unglaciated area, may be presumed to have been transported by water. Float of this character is also frequently followed by prospectors up the streams and slopes to its source. This process is too slow and difficult to be employed often by the examiner. But stream-transported float may ordinarily be assumed to have originated in the drainage basin where it is found, and scrutiny of the stream gravels may tell the examiner what to look for in a particular basin.

3. Float that has been transported by glaciers is subject to much the same conditions as water-transported float. It is usually to be recognized by its association with moraines and glacial sculpture but may sometimes be confused with float of the other two kinds. It is less feasible to find its source by systematic tracing than to find that of other float, but where the glaciation is local the parent ledge is likely to be near by and well exposed.

As placer deposits are really one form of float in the broadest sense, this may be the appropriate place to point out their value as indicating the auriferous character of the country rock of the drainage basin in which they are found.

It may be remarked, finally, that exceptionally, owing to migration of divides or their transgression by glaciers, float is found outside of the drainage basin in which it originated. This is most likely to be true of old stream gravels.

Prospects and mines.—An important part of the examining geologist's work is to note the location of all prospects and mines and to examine all of them, with the possible exception of those that are well known as producers. The most obviously useful data to be obtained from mining properties concern the value and visible quantity of the ore and the production if the property is producing. The examiner checks one against another his own observations, the information given by assay certificates and smelter returns, and the testimony of owners or mine officials, which may be in the form of an affidavit if it is thought desirable by an examiner who is empowered to administer an oath.

The information gathered from a prospect or mine may do much more than indicate the mineral or nonmineral character of the claim on which it is located and that of a little land in its immediate vicinity. The most useful clues may be obtained in openings which permit comparison between the appearance of a lode underground and that of its outcrop. By making these comparisons the examiner is much aided in recognizing the outcrops of important lodes that have not been opened, and by study of the geologic environment of prospected deposits he may form an opinion as to where others are most likely to be found.

Samples and assays.—Ore samples and assays showing their value give the most concrete evidence and have great weight at public hearings. To obtain abundant samples and assays, therefore, is one of the examiner's chief duties, and quantity of material is not more important than full information indicating its value as evidence. Samples collected by biased persons are taken only too often either from the best part of a lode or from the worst part, or even from the wall rocks; and the procuring of truly representative samples requires both judgment and honesty on the part of the examiner. Full records regarding the collection of the samples are indispensable. Even after every precaution is taken in the matter of collecting and record there may be much room for inference, for the weathered, superficial portion of a lode, which alone may be accessible, is sure to differ in tenor from the unweathered portion from which the valuable metals are partly or chiefly to be won. Where ores of the base metals are concerned, values may sometimes be estimated by inspection closely enough to dispense with assays. Usually, however, and especially if values in gold and silver are to be found, the classification of any large tract calls for many assays, and material to be assayed for precious metals must be collected with special precautions. Each sample must be large enough to suffice for several assays, so that any result whose accuracy is doubted may be checked, and the material must be broken up and well mixed to insure its homogeneity before it is divided into portions.

The Geological Survey does not make assays, not being provided with the proper equipment or a sufficient force. Its assay work is therefore done by custom assayers of established reputation.

History of the region.—The question sometimes arises whether the mining possibilities of a region are fairly represented by the extent to which it is developed. If a region contains few prospects and no mines, or if many of its prospects have been abandoned, is it or is it not because valuable metalliferous deposits are really absent? Some light may be shed upon this problem by the history of the region.

If the region has long been accessible and is known to have been well prospected, lack of development should have some weight against classification of land as mineral. It must be considered, on the other hand, whether local prejudice against some kind of country rock or gangue material may not have lessened the value of prospecting, or whether the region may not contain deposits of a kind that has not been looked for.

Abandonment of prospects may not always indicate the worthlessness of the lodes; it is sometimes due to the miner's failure to recognize valuable ores. Many metal prospectors have little knowledge of the appearance of ores other than those of gold, silver, copper, and lead and do not always recognize the secondary ores of copper, lead, and zinc. For this reason the dumps of abandoned mines may reveal ores of rarer metals or others not formerly used or commonly searched for by prospectors.

Mining methods and facilities often, of course, determine the success or failure of a mine, and it is proper to consider in every case whether abandonment may not have been caused by inefficient mining, crudity of methods, or difficulty of transportation. The transportation problem may be largely disregarded, for if a region develops good metalliferous deposits transportation is pretty certain to be provided in time, but the presence or absence of roads and trails has an important bearing on the accessibility of the region, which in turn is a factor of prime importance in deciding whether the absence of prospecting indicates the absence of valuable deposits.

BY-PRODUCTS OF MINERAL-LAND CLASSIFICATION.

VALUE OF COLLATERAL INFORMATION OBTAINED.

The process of classifying the public lands as to their mineral character involves the gathering of a large amount of information which is not only essential to the classification but valuable for other reasons. Furthermore, the accuracy and completeness of field observation necessary for classification afford an opportunity to record many facts which are entirely extraneous to the classification itself but

which may be now or at some later time of interest and value in other ways. These "by-products" of the process of land classification are of many kinds. Some are of value to home seekers and the public at large, others directly concern engineers and mining men, and still others are of present interest chiefly to scientists.

DATA OF DIRECT INTEREST TO THE PUBLIC AT LARGE.

While all information obtainable concerning the public domain is of ulterior interest to the people, information relating to such matters as the surface features, water supply, and character of the soil of a piece of land may prove to be of vital importance to the present or prospective settler. It is not practicable for the Geological Survey to make an exhaustive study of these features, but in the work of classification a certain amount of such information is always recorded. Thus, a map, supplemented by a written description, of each township examined for its mineral content is placed in the Survey files, showing in a rough way the agricultural character of the country. From these records it is possible to tell whether a section of land is suitable for dry farming or is adapted only to grazing, to obtain some idea of the number and size of the trees upon it, or to prepare a preliminary report as to its irrigability.

The field men engaged in work relating to land classification also record the position and size of all springs and water holes which they may find. This information is of direct value to the settler, but it also has another more general use. The more valuable agricultural lands of the public domain are rapidly passing into private ownership under the various settlement laws. It is recognized that most of the lands remaining are chiefly valuable for grazing or other uses not dependent on tillage, although the present laws do not adequately provide for their acquisition for these other uses. Congress has already given consideration to this problem and will doubtless reach a solution of it within the next few years. One of the most important factors to be considered in arriving at that solution will be the relation of the watering places to the range lands, for such lands can not be used without an accessible water supply. The accumulation of these data, therefore, in addition to being immediately useful to settlers and others, will be valuable in solving one of the public-land problems now confronting our lawmakers.

In studying and mapping a coal or phosphate bed it is necessary also to observe rather closely the geologic structure or attitude of the inclosing rocks. In some areas structure may have no bearing on mineral-land classification and yet may be valuable in determining the probability of obtaining a good well or of striking artesian water. The principles governing the flow of underground

water, though not generally understood by the layman, are yet comparatively simple, and a glance at the geologic map of a region may indicate at once the most favorable locality for sinking a well. As a minor illustration of the value of such information may be mentioned the fact that one of the geologists of the Survey had occasion during the summer of 1912 to advise two newly arrived settlers in the ceded lands of the Crow Indian Reservation, Mont., to sink their wells on the east side of a ridge rather than on the west side, as they had intended, because of the simple geologic fact that the rocks dip slightly to the east and the water follows down the dip, as is proved by the numerous springs on the east side and the few on the west. Such information is, of course, only of local application, but as the western country becomes more thickly settled and questions relating to city water supply arise, information of this kind gathered for the primary purpose of land classification may prove to be of considerable value.

Miscellaneous data of these types are utilized in various ways. Such of them as can with propriety be so used may be published in the bulletins in which the geologic material assembled in the course of land classification is made available for public use. Others, although not published and not used in mineral-land classification, are of the greatest value to the department in administering laws relating to nonmineral land, like the enlarged-homestead act, the desert-land law, or the Carey acts. Still others represent merely the accumulation of data likely to be needed if certain moot questions concerning public lands are to be decided by future legislation. All these actual or prospective uses, however, either directly or indirectly concern the public at large.

DATA RELATING TO PROSPECTING AND MINING.

Information regarding the character, location, and extent of each stratum of economic importance in the area examined forms a large part of the data on which classification is based. This information is published by the Survey in special bulletins or in the annual "Contributions to economic geology." A study of the map and of the plates of sections taken on the coal beds in any field, for example, will indicate to the prospective operator the most favorable location for a mine, and the text includes observations concerning the cover of the bed, the character of the roof and floor rocks, and the general structure, including faulting, of the inclosing strata.

Aside from the local and particular facts recorded for each area, as this work progresses the extent and character of each of the great mineral-bearing provinces are being accurately determined and more and more comprehensive and definite data concerning the mineral wealth available for the Nation's use are being gathered.

The study of the rock structure in an area is valuable not only in relation to its water supply, as has been indicated, but also as bearing on the occurrence of oil. The accumulation of oil and gas in the strata is governed by laws which are probably akin to those which direct the movement of water, and a knowledge of the rock structure is therefore, as a rule, of great assistance in the location of an oil well. Some new oil fields have been prospected and opened almost entirely on geologic evidence of this kind. It has also happened that the details of rock structure observed in a field examined merely for coal have been found to have an entirely new application and significance in subsequent prospecting for oil. In view of this close interrelation of geologic phenomena, therefore, the field geologist carefully records all the facts he observes in the course of his work, even though they appear to have no present bearing on the subject of land classification.

SCIENTIFIC DATA.

Data of interest at the present time chiefly to the scientist form another important "by-product" of the process of land classification. It is difficult, however, to select any group of facts as being of strictly scientific value alone, for new discoveries may at any time enlarge their significance and impart to them an unexpected economic importance. Many facts are, moreover, of equal interest to the pure scientist and to the engineer or the layman, so that while a great amount of scientific information has been collected in the work of land classification during the last six years, the purely economic value of much of it has already warranted the necessary expense.

Many data concerning the areal extent of different geologic formations have been gathered in the last few years and will be of use in connection with the geologic map of the United States which the Survey is now engaged in constructing. The stratigraphic relations of the formations, their composition, and their fossils constitute the only chronicle of conditions which have, at different times and divers places, existed on the earth. From this record some idea can be gained of the former geography of the country, of the great earth movements such as culminated in the formation of the Rocky Mountains, of the climatic conditions which formerly existed, and of the ancient plants and animals. These matters are at present chiefly of philosophic interest, but it has been by the accumulation of such facts in the past that science has been enabled to render valuable aid to mining and other industries. Furthermore, information of this kind, while perhaps of little present interest to the average layman, is of vital importance to the teachers of science in the universities of the country. As a case in point may be mentioned the recent discovery, by a Survey geologist engaged in the classification of coal

lands in New Mexico, of a great unconformity which separates into two formations a great thickness of strata that had hitherto been considered as a unit. This discovery is important not only on account of its strictly scientific bearing, but because it indicates that high-grade coking coal occurs in rocks of comparatively recent (Eocene) age.

It therefore appears that much important and diversified information is obtained in this way. Science is continually garnering facts against the time when their economic importance will appear, or when they may be correlated with other facts to furnish a broad hypothesis which may profoundly affect methods of prospecting or developing some mineral, such as oil. In addition, much local information of direct and immediate value to the mine operator or prospector is so gathered. Finally, the best obtainable record of the topography, water resources, and soils of the area examined is officially made. While the classification of public land is the immediate object of the work described in this bulletin, it is evident that such work, because of its exacting requirements as to accuracy and thoroughness, furnishes the best possible basis for valuable scientific generalizations.

CLASSIFICATION IN RELATION TO WATER RESOURCES.

GENERAL PRINCIPLES OF WATER UTILIZATION.

One of the most important factors in the development and use of the remaining public lands within the United States is water supply. The development of power, the extension of agriculture and grazing, the growth of mineral industries, transportation, and various other activities depend directly on the quantity and quality of the underground and surface waters in what is, generally speaking, an arid region. To dispose of or to administer the remaining public lands without reference to their water supply is to ignore that natural resource which will, perhaps more than any other, affect their future utilization.

Water is unique among the mineral resources of the earth in that, within natural limits, its supply is continually replenished and is therefore, in a large way, inexhaustible. That is to say, within the limits of the natural yield of a basin a certain minimum quantity of water will be available year after year in any river channel for irrigation, for city supply, or for power, as may be required. Aside from the inherent value of the water, the ownership of an important source of water supply becomes of the greatest consequence, for such ownership carries with it a measure of control, for an indefinite time, of all industries dependent on that particular source.

Statutes and court decisions both recognize that water should be devoted to its highest use, and the laws of many States provide for the condemnation of an inferior use in the interest of a higher one. Such laws generally recognize a municipal or domestic use of water as the highest which may be made, because of its necessity in the support of life. Next in order comes the use of water in agriculture for irrigation, whereby the available food supply is affected. The use of water for power, though important and valuable, is inferior to either municipal use or use for irrigation and may, in general, be condemned if necessary to insure higher utilization. The greatest value of a source of water supply at any particular time will depend, however, on the demands for domestic or municipal use, on the proximity of a tract of arable land adapted to agriculture, and on the quantity of power that may be developed and the availability of a market for it. Such value may change with the development of the country, making necessary the abandonment of established industries in order that the water may be available to supply a greater need. Changes in use will, however, follow the economic law, as the damage to established industries must be paid for, and to that extent the cost of the water for other use will be enhanced.

Important conditions are inherent in the use of water for various purposes. Its use for power affects neither its quality nor its quantity, but its use for irrigation depletes its quantity and its municipal or domestic use not only depletes its quantity but impairs its quality. Various uses may be and in many places are compatible with one another. In other places the conflict in use may be only partial. Many of the most advantageous sites for developing power, which, under conditions of modern long-distance transmission, are not dependent on a near-by power market for their value, are located in the upper portions of river basins, where the slopes are steepest and where demands for other use are not likely to be made. Under such conditions the water may be utilized in a power plant or a series of power plants and still be available for other purposes by the sacrifice of only so much of the power head as may be necessary to obtain adequate pressure in the pipes of the city water mains or to maintain the elevation of canals required to cover irrigable lands. In similar manner water that has been used for a municipal supply may still be available, as sewage, for a certain amount of irrigation. The equalization of the stream flow in order to insure a continuous output of power will in general increase the value of the stream for municipal use. The use of water for irrigation, on the other hand, is limited to the growing season and requires the concentration of flow in accordance with the needs of crops during that season. The complete utilization for irrigation of a stream whose flow has been equalized for power will make necessary storage below the power plant of the

flow of the nonirrigation season in order to render it available for the irrigation of crops in the following growing season. The practicability of such storage and redistribution of flow will depend on local topography and must be determined for each locality. The conditions which affect the present and future practicable utilization of water are therefore very complicated, and the classification of land as regards its water resources is correspondingly difficult.

In general the development and use of valuable power sites involves the construction of expensive systems for transmitting the power to distant markets and distributing it among small customers. A water-power development can be most fully utilized and therefore has its greatest value when connected into a system containing other hydroelectric or steam-power plants, because a large system will generally have relatively uniform power requirements on account of the varied use of the power and also a relatively flexible power output on account of the steam plants and of the storage capacity which may be available in connection with some or all of the water-power plants. In view of these conditions the combination of power plants into big systems is natural and tends to more economical and more complete utilization of the power resources. As a duplication of such a power system in any territory is uneconomical and in general is impracticable, a monopoly of the power market results, and such monopoly, if subject to proper public control, should be encouraged. Monopolistic tendencies in the control of water resources entail difficulties and dangers that have been recognized by Congress, as manifested by the laws governing rights of way, especially for the purpose of developing and transmitting power, on or across the public lands.

The protection of the people against the possible bad effects of monopoly and the retention of control of the use of this important source of power, which may be expected to increase in value with the decrease in available fuels, is at present accomplished by the United States through ownership of the land which is required for the use of the water resources. Congress has provided no means for the alienation of power lands as such and has sanctioned their use for commercial purposes only under a limited permit revocable by the secretary of the department having jurisdiction. It provided for rights of way for power-transmission lines under the same law but by a later act has authorized a fixed tenure for a period not exceeding 50 years.

CLASSIFICATION OF WATER-POWER SITES.

PRELIMINARY WITHDRAWALS.

The classification of lands as water-power sites and their reservation under the acts authorizing withdrawals is in general first made in the absence of detailed examination to determine power value and

is of a preliminary or tentative character. Examination in the field provides a satisfactory basis for final classification and adjustment of withdrawals. The following paragraphs relate more particularly to preliminary classification and withdrawal but describe also the routine procedure followed and records prepared in all withdrawals for power-site purposes.

The principal steps taken in connection with the making of power-site and reservoir withdrawals are as follows:

1. Initiation of search for possible power or reservoir sites. The possibility of the existence of valuable power resources is brought to the attention of those charged with the duty of recommending withdrawals through general probability that such sites may exist, through requests for report on the possibility of there being such sites, or through information as to the possible existence of such sites derived from reports of field employees of the Geological Survey or other offices, from news items, from newly published maps, from the filing of applications for rights of way, and from other sources.

In general the initiative in the premises is taken by the Geological Survey, but it not infrequently occurs that some power company intending to make surveys for a hydro-electric development in new territory requests the withdrawal of the lands likely to be occupied. The purpose served by withdrawal of such lands is two-fold. The valuable power sites that might otherwise be alienated as nonmetalliferous claims, timber and stone entries, agricultural entries, or for some other purpose, are retained in public ownership, and the company or person eventually developing the resource, presumably but by no means necessarily the one who requested the withdrawal, is protected from the intervention of other rights and has merely to acquire the necessary rights from the United States instead of from the United States and a host of persons who might otherwise have succeeded to ownership of the land.

2. Estimation of character and value of probable development and approximate description of the lands under consideration. This step involves an examination of existing data on stream flow and rainfall, as well as of maps, engineering reports, and all other available sources of information. In some cases information definite and conclusive in character may be brought to light. On the other hand, it frequently happens that estimates of stream flow must be based on nothing more reliable than conditions of run-off in basins many miles distant and that estimates of available head for power development must be derived from elevations at scattered points culled from railroad folders and similar data of doubtful applicability.

3. Examination of status of lands and definite description of lands to be included in the order of withdrawal. The lands presumed to be valuable for power or reservoir sites are platted on township plats

of the public survey or tracings of them, and the status of the lands as to ownership is ascertained by examination of the records of the General Land Office and indicated on the township plats or tracings. All patented lands are eliminated from further consideration. Lands which are covered by location or entry but title to which still remains in the United States are included in withdrawals to the end that the order of withdrawal may become effective if for any reason the lands do not proceed to patent. Such withdrawal in no way affects the rights of an entryman who proceeds with the acquisition of his claim in accordance with the law, but it immediately becomes operative in case the claim is abandoned or for any reason becomes invalid.

Definite description of the surveyed lands to be withdrawn is made by legal subdivisions in conformity with the official survey. Unsurveyed lands are described by townships and some lands in townships that are partly surveyed by sections, in accordance with the probable protraction of the public survey; also by distance from the stream or streams having value as a source of power, in some such phrase as "all land within half a mile of Snake River."

All withdrawals are so made as to include the least area that will effectively protect the resources involved. Where data are meager or defective the withdrawals are at first necessarily of relatively great extent but are eventually reduced as more definite and reliable data are acquired. The area of the land to be withdrawn in each township is compiled from the plats of the public survey, or estimated for unsurveyed lands, and the total area of the withdrawal is computed.

4. Preparation of order of withdrawal. The draft of a formal order of withdrawal is next prepared, together with a letter to the Secretary of the Interior transmitting the order and recommending its approval. On approval by the Secretary of the Interior orders of withdrawal are transmitted to the President for his consideration and become effective on his approval. The following order is typical of the present form of withdrawals under the acts of June 25, 1910 (36 Stat., 847), and August 24, 1912 (37 Stat., 497):

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
October 12, 1912.

The honorable the SECRETARY OF THE INTERIOR.

SIR: In accordance with your general instruction, I recommend the withdrawal for water-power sites of the following areas, involving 240 acres. This order of withdrawal includes no lands covered by enlarged-homestead designations.

Very respectfully,

GEO. OTIS SMITH,
Director.

OCTOBER 19, 1912.

Respectfully referred to the President with favorable recommendation.

SAMUEL ADAMS,
Acting Secretary.

ORDER OF WITHDRAWAL.

Power-Site Reserve No. 299.

Mill Creek, California.

Under and pursuant to the provisions of the act of Congress approved June 25, 1910 (36 Stat., 847), entitled "An act to authorize the President of the United States to make withdrawals of public lands in certain cases," as amended by the act of Congress approved August 24, 1912 (37 Stat., 497), it is hereby ordered that the following described lands be, and the same are hereby, withdrawn from settlement, location, sale, or entry and reserved for water-power sites:

Mount Diablo meridian.

T. 26 N., R. 1 W., sec. 24, SE. $\frac{1}{4}$ of SE. $\frac{1}{4}$;
 sec. 26, SE. $\frac{1}{4}$ of NE. $\frac{1}{4}$, SW. $\frac{1}{4}$ of NW. $\frac{1}{4}$, NW. $\frac{1}{4}$ of SW. $\frac{1}{4}$;
 sec. 32, S. $\frac{1}{4}$ of SW. $\frac{1}{4}$.

WM. H. TAFT,

OCTOBER 18, 1912.

President.

Orders of withdrawal affecting lands within Indian reservations, made under sections 13 and 14 of the act of June 25, 1910 (36 Stat., 855, 858), are forwarded to the Secretary of the Interior through the Office of Indian Affairs. The following order illustrates the form in which such withdrawals are now made:

DEPARTMENT OF THE INTERIOR,

UNITED STATES GEOLOGICAL SURVEY,

Washington, May 23, 1912.

The honorable the SECRETARY OF THE INTERIOR

(through the Commissioner of Indian Affairs).

SIR: In accordance with your general instructions, I recommend the withdrawal for water-power sites of the following areas, involving approximately 6,817 acres (in the Blackfeet Indian Reservation).

Very respectfully,

H. C. RIZER,

Acting Director.

JUNE 18, 1912.

I concur in the above recommendation.

R. G. VALENTINE,

Commissioner of Indian Affairs.

ORDER OF WITHDRAWAL.

Power-Site Reserve No. 275.

St. Mary River Tributaries, Montana.

It is hereby ordered that the following described lands, valuable for power sites, be, and the same are hereby, reserved from location, entry, sale, allotment, or other appropriation in accordance with the provisions of the act approved June 25, 1910 (36 Stat., 855), and that no trust or fee-simple patent be issued as regards these lands until further orders:

Montana meridian.

[Description of lands.]

SAMUEL ADAMS,
First Assistant Secretary.

JUNE 22, 1912.

Withdrawals of this form receive the concurrence of the Commissioner of Indian Affairs before being forwarded to the Secretary of the Interior and become effective on approval by the Secretary, no action by the President being contemplated by the law.

Copies of approved orders of withdrawal are furnished to the Geological Survey, to the Office of Indian Affairs if affecting Indian lands, and to the General Land Office, and notification thereof is sent to the local land office of each district in which the reserved lands are located. Notation of the withdrawal is thereupon made on the tract records of the General and local land offices. Thereafter entries inconsistent with the purpose of the withdrawal, except under the mining laws pertaining to metalliferous minerals, are rejected. Modifications of a withdrawal may, however, be made to permit the allowance of an application that will subserve the purpose of the withdrawal or that involves a more beneficial use of the land than could be had under the purpose of the withdrawal. Withdrawals therefore in no way interfere with the proper development of the resources involved but tend toward their most complete and beneficial utilization.

5. Preparation of minutes. At the time each order of withdrawal is prepared minutes are written setting forth the object sought to be attained by the withdrawal, the extent and value of the resources involved, the data on which the withdrawal is based, and other pertinent facts. Orders of withdrawal are numbered consecutively in chronologic order, and successive withdrawals on any stream are also given consecutive numbers in connection with the stream name. The various sets of minutes for withdrawals on any stream therefore constitute a concise statement of its value for power or reservoir sites and of the data relating thereto.

6. Office records. When notice of the approval of an order of withdrawal is received at the Survey, the withdrawn area is plotted and numbered on a General Land Office State map. A township card is prepared for each township affected, showing the location of the stream and indicating the legal subdivisions withdrawn and the number of the withdrawal. If more than one withdrawal is made in a township, the card is prepared so as to show the withdrawals separately and constitutes a graphic record of all withdrawals and restorations of withdrawn lands. The numbers and dates of recommendation and approval of all power-site withdrawals and restorations

involved are tabulated on the back of the card. The front of a typical township card is shown in figure 8.

In a ledger kept for withdrawals and restorations are noted, when the order is prepared, the number and area of the withdrawal or restoration and the date of the recommendation of the Geological Survey. The date of approval is also noted in the ledger when the copy of the approved order is received.

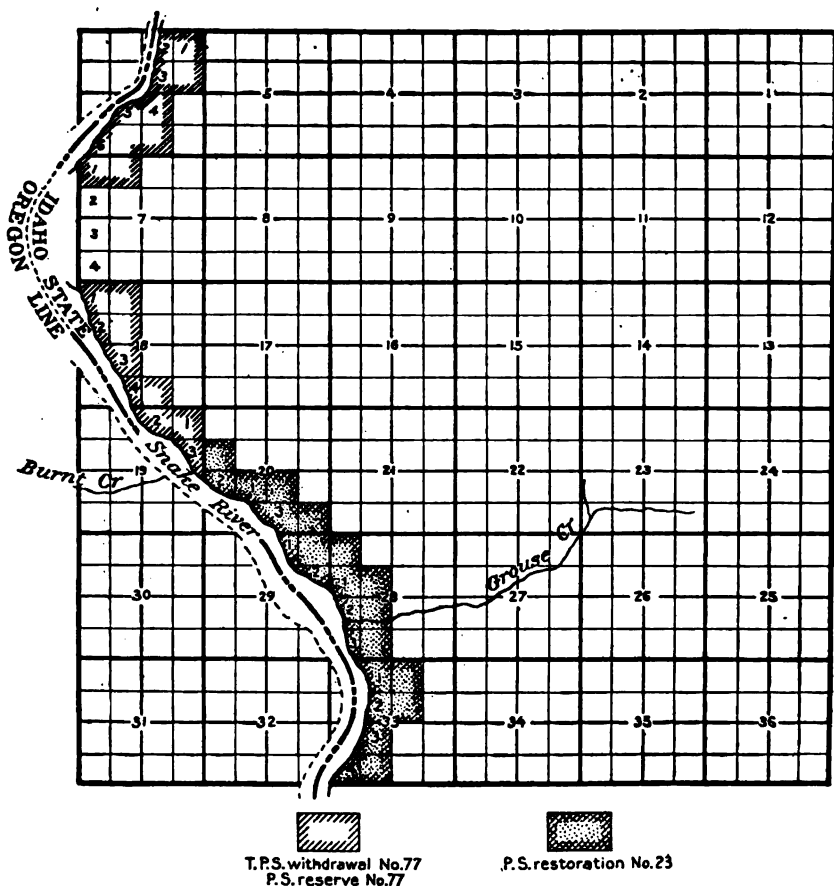


FIGURE 8.—Typical township card illustrating action taken by United States Geological Survey on power sites.

The complete record of the Survey relating to a power-site withdrawal consists of the following items:

- (a) Order of withdrawal, filed by withdrawal number and therefore chronologically.
- (b) Minutes, filed by number of withdrawal and therefore chronologically.
- (c) Township plats showing status of lands as to ownership, filed in binders by number of withdrawal and arranged by principal meridian, range, and township.

(d) Township cards showing the extent and date of withdrawals and restorations, filed by States and arranged by principal meridian, range, and township.

(e) Mounted State map on which withdrawals and restorations are platted.

(f) Withdrawal ledger in which is kept a chronologic record of withdrawals and restorations showing the number, area, date of recommendation, and date of approval.

METHODS OF FIELD EXAMINATION.

DIVERSITY OF CONDITIONS.

The examination of lands and conditions along any stream for the purpose of locating a feasible power site is a fairly common and well-defined engineering operation. The examination of lands and conditions for the purpose of classifying the lands according to "power value," as the expression is interpreted in this bulletin, is quite another matter. In the first case, the effort is made to locate one or more sites that appear best adapted for development under the prescribed conditions of cost and prospective market which prevail at that particular time. The study is concentrated on the lands that will be involved in that particular development. In the second case, all the lands in public ownership adjoining or near the stream are presented for consideration, and the problem is to determine whether any or all of these lands could be used in the development of any feasible power site. Moreover, the feasibility can not be settled on the basis of present limitations of development but must be determined according to what are believed to be the limitations of a future day, when water power will be a more vital factor in our economy than it is now and when, by reason of increased demand, a development whose unit cost would now be too great would become thoroughly practicable. Power sites are classified according to their future possible utility as well as according to their present value.

There are other features which still further broaden the scope of an investigation of the kind here described. It is necessary to determine whether the lands examined may not be more beneficially devoted to the use of water for domestic supply or for irrigation than for power, and whether their use for power may not be prejudicial to the other uses at the site in question or at some other site more or less remote.

It must also be determined in many cases whether the land itself, irrespective of any distant lands which may be served, is of more value for agriculture or as a town or manufacturing site than as a power site. Such a consideration applies especially to lands that may be suitable for storage reservoirs. Usually the civic, industrial, or rural improvements that have previously been made in a reservoir site largely control the decision on this point, but the cases in which such influences are absent are still relatively frequent. Therefore

the field of investigation again spreads beyond the actualities of the present and an estimate of prospective events must be made.

Finally, it must not be forgotten that human activities are not confined to the utilization of water—that a community which produces must, if its products are of value, have suitable means of transportation. Therefore it frequently occurs that consideration must be given to the relative usefulness of a piece of land as a power site or as a right of way for a railroad. In some places the bottom of a canyon that is suitable for power development or a basin that is suitable for a reservoir is also an advantageous railroad route. Although it is usually possible to locate an alternate railroad route, the cost of utilizing it may be so great as to outweigh the advantages that may accrue from development of power along the stream. It is thus necessary to appraise the relative values and comparative costs and choose the course that is or is likely to become of the highest human benefit.

The classification of lands for water-power sites therefore requires a broad perspective, and it comprehends the study of so many variable conditions and prospective changes in public demand that mistakes are easily made and mature consideration is always necessary. Field examination naturally falls into two classes. The first is reconnaissance, made in response to urgency. The second is final and detailed and involves all the precision of instrumental work and the careful deductions made possible thereby.

RECONNAISSANCE EXAMINATION.

A suitable report on a water-power site classification should cover as many of the subjects listed in the following syllabus as may be relevant:

- I. Sources of data used in report :
 1. Personal examination—route followed and time consumed.
 2. Water-supply papers.
 3. Maps.
 4. Reports of engineers.
 5. Miscellaneous.
- II. General introductory description, including location as to State, rivers, cities, township, and range.
- III. Description of the power developments and possibilities on the river, showing by sketch on best available maps location of dams, power canals, and power houses already constructed and possible location of these essential features for other power developments. Ownership of plants already constructed and use made of the power.
- IV. Physical characteristics :
 1. Topography at dam site.
 2. Relation of tract to a possible power development described under III above.
 3. Head available, how secured, whether by dam or by dam and canal.
 4. Character of dam sites, holding ground for canals, and site for power house.

V. Water supply:

1. General description of drainage area.
2. Actual records if available, showing maximum, minimum, and mean discharge for each month, also absolute seven-day minimum for the year.
3. Storage already developed.
4. Storage possibilities:
 - (a) Location of reservoir sites.
 - (b) Height of dam.
 - (c) Capacity of reservoir.
5. Prior water rights above and below power site.
6. Ice conditions during winter months:
 - (a) Without storage.
 - (b) With storage.

VI. Possible power development:

1. Horsepower at wheel shaft (without storage).
2. Horsepower at wheel shaft (with storage).

VII. Cost of power development:

1. Cost of diversion or forebay dam.
2. Cost of canals.
3. Approximate cost of complete installation per horsepower developed:
 - (a) Without storage.
 - (b) With storage.

VIII. Market for power:

1. Present.
2. Future.
3. Length of transmission lines, etc.

IX. Suggestions and recommendations:

1. Relative to lands withdrawn.
2. Relative to other public land which has or may have value for development or transmission of power.

X. Appendixes:

1. Water-supply records.
2. Maps.
3. Pictures.

Before entering upon field work the hydraulic engineer should collect all available topographic and hydrometric data relating to the stream under investigation. For many streams the topographic data may be obtained from the United States Geological Survey topographic sheets, the United States Land Office township plats, county and other maps, or railroad location surveys and profiles. Study should also be made of the precipitation records collected by the United States Weather Bureau and the river-discharge records made by the United States Geological Survey and by private citizens. After obtaining in advance as much information as may be available, the engineer proceeds to the field. His instrumental equipment usually consists of hand level, steel tape, aneroid barometer, compass with sight alidade, and camera. In some investigations it is necessary to carry a current meter. These instruments and the notes, maps, and other data procured in advance, together with a map or de-

scription of the locations of the public land along the stream valley, constitute the working equipment. The engineer travels by wagon, on horseback with pack outfit, by boat, or on foot, as the conditions may require, and his personal equipment is made appropriate to the conditions.

The engineer, after examining all the lands in the stream valley and studying the relation of the critical features to the public lands, constructs what may be called a mental picture of the situation in its most productive condition of water-power development. He also works out the variations which might be made in his plan of development, knowing well that no other engineer covering the same ground independently would conceive the identical plan of development that he would. It is even necessary for the engineer to consider plans and possibilities that may appear to him impracticable or fantastic, for the serious proposal of such plans is a frequent occurrence in the routine experience of the department, and a relatively superficial glance over the country gives evidence that many such plans have been put into effect. Especially is it necessary for the engineer to gather local information concerning proposed developments of all kinds and to obtain as many working details of such developments as may be possible. To this end it is frequently essential to follow up rumors of prospective development. Although most of these rumors may prove inconsequential, they now and then lead to information whose importance fully compensates for the time spent on rumors that have no basis in fact.

If the engineer's investigations show that the slope of a river along a certain section affords a working head which, in connection with the known or supposed flow of the stream, indicates the possibility of a power site, he determines in a rough way the method or methods by which that site may be utilized. It is unnecessary for him to make final location surveys, because the fact that the power site exists is usually sufficient for the purposes at hand. The particular method of development will eventually be determined largely by the state of the science at the time the development is to be made. It is recognized that the details of location and equipment depend on the progress attained at the time of construction. We know, for example, of many old developments which if constructed to-day would be of an entirely different type.

The standards of capacity which warrant the withdrawal of public lands for power sites vary with the location, and in many cases the decision rests largely on the abundance of power sites in the immediate region. A stretch of river having a fall of 10 feet to the mile may, in regions where power sites are not abundant, be worthy of withdrawal, whereas a similar stretch in a region abundantly supplied with sites of greater capacity may not be of sufficient im-

portance for departmental action. The determination of the proper course is difficult, for the question of feasibility must be partly answered with regard to future conditions. All the factors discussed in the beginning of this section, such as domestic water supply, irrigation, and transportation, must be borne in mind, and it is imperative that the engineer remember the fact that Government control of a small amount of land may be quite as effectual in the ultimate control of the development at the power site as if every element of that site were in public ownership. A small tract of land, even a fractional subdivision, located within a storage-reservoir site or along a diversion right of way has been sufficient to determine the control of the development. Having reached a decision on all the points above discussed, the engineer makes appropriate report.

Detailed surveys are not attempted in reconnaissance work. Approximate cross sections are taken at possible dam sites and, after the most feasible height of the dam is determined, a rough estimate of the area that would be submerged is made by means of the hand level. Where no profile of the stream channel is available, the fall over a short distance is determined with an aneroid barometer. This instrument, however, must be used with caution, especially during changeable weather. Photographs of all the critical points are taken. The possible dam sites suitable for storage or for diversion having been located and the type of development roughly determined, it is then necessary to consider the run-off. If the problem is one of storage, it will be sufficient to know the approximate mean annual run-off; the height of the storage dam can then be so fixed that the capacity of the reservoir may, as nearly as practicable, be sufficient to afford complete control. Of course, as a rule, sufficient storage capacity is not available, yet on the other hand there are situations in which the dam might be raised to a height that would give greater storage capacity than is necessary. In case no storage is to be provided, the mean daily flow of the stream must, if possible, be determined in order that the primary power capacity of the site may be appraised. If the available site is located in a canyon, it becomes necessary to determine within reasonable limits whether the maximum fall may be secured by a low diversion dam and conduits or whether it would be more economical to obtain the necessary height by the construction of a high dam.

Much of the land along the streams of the West has passed into private ownership, and where good facilities exist for the development of water power or the diversion of water for irrigation private interests may have established rights to the use of the water. Another complication on many streams consists in the location of railroad rights of way. Thus the problem of land classification may be

greatly complicated, and considerable thought and good judgment are required to determine on a plan whereby the stream may be utilized to a reasonable capacity and the vested rights already acquired by private owners may not be violated. Many of the power plants already installed use only a small percentage of the maximum available power. In such cases either the plans for ultimate maximum power development involve the utilization and enlargement or improvement of such plants or they are omitted from consideration, it being assumed that when the demand for power increases to a certain point ordinary commercial procedure will settle all questions relative to the destiny of power plants in operation.

In case a railroad is already constructed parallel to the stream, plans for immediate development must avoid any interference with the railroad rights. Few plans that would require relocation of railroads are feasible under present market conditions, but the future demand for power will probably change the aspect of the case, and on this account the problem is treated as if the railroad did not exist, it being assumed that whenever the demand for power is sufficient to justify the expense of railroad relocation the power will be developed. It is quite as desirable to provide means for future control by the Government in such an event as it is to provide such control in situations where no complications of this kind exist. Therefore, an important part of the field work consists in the determination of possible relocations, so that in fixing the value of any land reserved for a power site the department may have information whereby it can render an opinion as to the possibility and cost of relocating such lines as are already constructed or as to the feasibility of requiring the relocation of rights of way for which application may subsequently be made.

DETAILED FIELD INVESTIGATIONS.

Investigations of detailed character are made to obtain data for final departmental action. The statements in the preceding section indicate that the chief object of the reconnaissance work is to locate lands suitable for power sites. The capacity of the power sites is determined in connection with such work largely for the purpose of justifying the preliminary withdrawal of the lands from entry. Incidental information of a more or less final character is collected during the reconnaissance examination, for the most part with a view to convenience and economy in the final detailed surveys. The withdrawals of lands for power sites on the basis of a reconnaissance examination are usually made liberal in extent, the purpose being to restore to entry any of the legal subdivisions which on detailed survey prove to be of no value in connection with the plans finally

adopted. The detailed investigation consists of surveys to determine river profiles, surveys of reservoir site, soundings at dam sites and other places, and a more or less careful examination of the character of the underlying formations that must serve as foundations, especially for dams. In addition, it is necessary to establish river gaging stations, if none have already been established, for the purpose of determining, with a high degree of accuracy, the amount of water discharged by the river, so that the economic capacity of the reservoirs and power plants may be determined.

The gaging stations are selected, equipped, and maintained according to the standard methods followed by the United States Geological Survey in its regular hydrometric work. The processes are fully described in the annual progress reports on investigations of stream flow published by the Survey.

The investigation of dam sites for the purpose of determining the security of the underlying formations that must serve as foundations has, up to the present time, been based largely on general geologic information concerning the holding qualities of the formations known to exist in the localities examined. Final work of this character, none of which has been attempted in connection with the classification of water-power sites, will consist of the usual soundings and borings to determine the depth of the holding material, its permeability, its strength, and all the other factors that enter into its suitability for foundations.

Special river surveys delineating the alinement and water-surface contours of streams and the topography of the adjacent land are made on a scale of 2 inches to the mile by the plane-table and stadia method. The survey maps are accompanied by profiles showing clearly the stream gradient. The contour interval on water surfaces is usually taken as 5 feet but may be increased to 25 or even to 100 feet for sections of steep slope where the delineation of a lesser interval could not be clearly made. The topography of the land adjacent to the stream is shown by a contour interval of 25 feet and in general is carried to an elevation 100 feet above the stream by survey and an additional 100 feet by sketching. General features of culture, gaging stations, existing hydraulic works, all lines of land subdivisions by public survey, and other relevant data are shown on these maps. Promising reservoir and dam sites are shown with contour intervals of 5 feet to an elevation equal to the height of the possible dam.

Engineers executing these surveys are instructed to obtain and furnish to the Washington office all available data as to the water resources involved, supplementing the data shown on the maps by detailed description of existing or proposed developments.

COMPILATION OF RESULTS AND REVISION OF WITHDRAWALS.

When results of field investigation are available, much the same procedure is followed in the office in revising withdrawals as in making the preliminary withdrawals. The problem at this stage becomes one of limiting the withdrawals to the least possible area. Careful scrutiny of plans and profiles of the streams makes it possible to determine the power value of each smallest legal subdivision, and withdrawn areas containing no sites that are or may be valuable for the development of power are restored to the public domain. If the stream is of relatively flat gradient, where power development must be restricted to the low-head type and the construction will consist of power houses in conjunction with dams developing the available head, it is possible in many cases to locate definitely the favorable dam sites and divide the stream into successive units of probable development, from which no very great departure in construction is likely. On such streams the power-site reserves can be defined with a high degree of accuracy, and the use of each tract, whether for dam site, power-house site, flowage, or other purpose, can be forecast with considerable assurance. A minimum area of land is retained in power-site reserves on such streams. If the stream has a relatively steep gradient, however, where the natural development for power will consist of a low diversion dam and a long conduit leading to a power house perhaps several miles below and developing a high effective head, there can be a wide range of selection for the units of a comprehensive power project. On such a stream no specially favorable dam site is necessary, and relative expense of construction is generally the factor determining a choice among several different locations for the conduit. A definite use for any particular tract can seldom be assigned with development of this type, and the power-site reserve must be maintained so as to include all possible conduit locations if it is to be effective. A final revision of withdrawals along such a stream must be made as the power sites are developed. Even in such cases, however, restorations are frequently possible as soon as field examinations are made.

Restorations are recommended by the Survey and recorded in the Survey files in much the same way as withdrawals. The usual form of power-site restoration is as follows:

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
Washington, November 12, 1912.

The honorable the SECRETARY OF THE INTERIOR.

SIR: Investigation of lands included in power-site reserve No. 117, Snake River, Idaho, indicates that the portion of the lands included therein described in the following order of restoration is not valuable for the conservation of

water power, and I therefore recommend that the said order of restoration be submitted to the President for appropriate action. The area involved in this restoration is 85.7 acres.

Very respectfully,

GEO. OTIS SMITH,
Director.

DECEMBER 3, 1912.

Respectfully referred to the President with favorable recommendation.

WALTER L. FISHER,
Secretary.

ORDER OF RESTORATION No. 82.

Snake River, Idaho.

So much of the orders of withdrawal made heretofore for the purpose of reserving water-power sites as affects the lands hereinafter described is hereby revoked.

And it is further ordered that all of such lands not otherwise reserved or withdrawn are hereby restored to the public domain and shall become subject to settlement and entry under the laws applicable thereto upon such date and after such notice as may be determined upon by the Secretary of the Interior.

Boise meridian.

T. 5 S., R. 4 E., sec. 30, lot 6;
sec. 32, lots 7 and 8.

WM. H. TAFT,
President.

DECEMBER 3, 1912.

ADVERSE CLAIMS.

In many cases there is a conflict between the purposes of a power-site reserve and of some other claim to or proposed use of the lands affected. There is at present no satisfactory law under which land withdrawn for power purposes under the acts of June 25, 1910 (36 Stat., 847), and August 24, 1912 (37 Stat., 497), can be used for other purposes without jeopardizing the interest of the United States in the power possibilities. Under the acts relating to rights of way title to land by legal subdivisions is not granted and, as described elsewhere (p. 28), the interest of the United States may be preserved. Under the laws relating to agricultural land and mining, however, title to the land embraced in entries or claims passes from the United States and there appears to be no way in which the power estate may be satisfactorily reserved. Relative priority of reserve and claim, special exceptions, and relative value are the principles that govern in adjudicating the conflict. A power-site withdrawal is of no effect as against bona fide metalliferous mineral claims, without regard to priority of initiation. A power-site withdrawal is without effect as against a prior occupant or claimant of oil or gas lands who is diligently prosecuting work leading to discovery, but it becomes immediately effective against such occupant or claimant if diligent

prosecution of work leading to discovery is discontinued. A power-site withdrawal is without effect as against a valid subsisting homestead or desert-land entry or claim of valid settlement so long as it is maintained and perfected pursuant to law, but the withdrawal becomes effective whenever the entryman or settler no longer continues to comply with the law under which the entry or settlement was made. With the foregoing exceptions, a power-site withdrawal under the acts of June 25, 1910, and August 24, 1912, is effective against all claims or entries on which rights have not vested prior to the date of the withdrawal.

Withdrawn lands having valuable possibilities for the development of power are alienated in the usual way if they are included in the excepted classes described above, although possibly the claims for such lands are subjected to a more careful scrutiny. If it appears that the claimant is attempting to obtain title to land because of its value for power, and if its power value is greater than its value for the alleged purpose of the claim, patent may be refused and the entry canceled. Cases of this nature arise most frequently in connection with metalliferous mineral entries, although not a few power sites have been homesteaded or acquired under the timber and stone law.

In the case of claims against which a power-site withdrawal is effective, a most unfortunate situation occasionally arises. For example, title to land may be sought by the application of scrip, and the claim may be initiated in advance of a power-site withdrawal. The claimant may have expended considerable sums in improvement and cultivation and have proceeded throughout in good faith. Nevertheless, the land sought to be acquired may be worth for power many times its agricultural value, and when this dominant power value is ascertained the land is naturally included in a power-site reserve. In such cases it is always a grave question whether the public interest is best served by the defeat or confirmation of the claim. Under the strict rule of the law the claimant has no rights in the case. No provision of law makes it possible to give him agricultural rights and reserve to the United States the rights of power development. Unless, therefore, the value of the land for the development of power is so great as to demand reservation for that purpose, public interest appears to sanction the claim of the individual as against that of the Nation, and elimination of the land from the power-site reserve is recommended.

NONPOWER CLASSIFICATION.

In connection with the office studies incident to the report on the power-site possibilities of lands embraced in subsisting claims and with the investigation of power sites a mass of information is

gradually being accumulated. This information is of negative as well as of positive character and shows where power sites are not located as well as where they are located. For convenience in making later reports on adjacent areas, this information is summarized from time to time and State maps are prepared showing the lands that are of no value for power development. This essentially constitutes a negative power classification and the use of such maps greatly facilitates the future work. In connection with these maps minutes are prepared in which are set forth the data on which the classification is based and the conclusions drawn therefrom.

ADDITIONAL REQUIREMENTS TO MAKE POWER CLASSIFICATION EFFECTIVE.

In order that the classification of land as chiefly valuable for the development of power may be made effective, it appears desirable that there be additional legislation providing for the control and utilization of land so classified under such conditions and regulations as Congress may decide to be necessary and for the proper administration of such land if, as now seems desirable, the title is to be retained in the United States.

As a feature, or perhaps as a preliminary step in such legislation, a "separation act" would be desirable, providing for the disposition of power and agricultural estates independently of each other in a manner similar to that now provided for coal land and for oil and gas land in Utah. Such independent disposition of these estates is believed to be entirely feasible, because, except where reservoirs are provided, the land actually occupied by a power plant constitutes only a small part of the legal subdivisions on which the dam, flowage, water conduits, power house, and transmission lines are located. The bulk of the land is available for agricultural or other use and may be largely so utilized without detriment to the power development.

The alienation of the agricultural estate and the retention of the water-power estate in any land, with provision for payment of proper damages to the agricultural estate when the power is developed, appears to be practicable and desirable in the interest of the orderly development of the natural resources involved. In fact, a separation of estates and a disposition of each estate as such appear to be desirable, even though it may be decided not to retain control by the United States of the water-power estate.

Whether or not a law providing for separation of the power estate is enacted, laws providing for the development of power on public land under such conditions that the industry would be materially encouraged and capital attracted would be most beneficial. The true purpose of power-site withdrawals is the use of valuable power lands primarily for developing power, not the withholding of such lands

from any use. It is true that withdrawn lands are now available for use under the right of way acts, but they can be used for power development only under a permit revocable at will. Such a method is hopelessly inadequate and tends to discourage development. Recommendations for additional legislation have been repeatedly made by the department, and several very satisfactory bills have been introduced in Congress, but so far no suitable laws have been enacted.

CLASSIFICATION OF LANDS AS REGARDS IRRIGABILITY.

FIELD METHODS.

GENERAL CONSIDERATIONS.

The general considerations and particular features already discussed under "Classification of power sites" apply to the classification with respect to irrigability. They include determination of the relative value of water in its different uses and, in the case of reservoirs and headworks, the value of the land for other purposes. The field of investigation must be quite as broad and comprehensive for this purpose as for the classification of water-power sites. The engineer who performs the investigation is required to equip himself with the preliminary facts available in the office, such as maps and records of stream flow, and his instrumental equipment is practically the same as that already described.

A suitable report on the classification of lands as regards irrigability should cover as many of the subjects listed in the following syllabus as may be relevant:

I. Sources of data used in report:

1. Personal examination; route followed and time consumed.
2. Water-supply papers.
3. Maps.
4. Reports of engineers.
5. Miscellaneous.

II. General introductory description:

1. Name of project.
2. Where located.
3. When started.
4. Estimated time of completion.
5. Concise description of project, including—
 - (a) Area involved.
 - (b) Source of water supply.
 - (c) Outline of irrigation system.
 - (d) Important or critical structures involved.
6. Nature and extent of control of the lands:
 - (a) Carey Act.
 - (b) Municipal district.
 - (c) Ownership by developing company.
 - (d) Contracts with land owners.
 - (e) Contracts with desert-land or homestead entrymen who have no titles.
7. Railroad and other transportation facilities.

III. Rights of way :

1. Ownership and extent of those already secured.
2. Applicants for those pending.
3. Additional, across public lands, needed for the complete project.

IV. The lands :

1. Topography.
2. Geology.
3. Vegetation.
4. Soil :
 - (a) Soil analysis.
 - (b) Depth of soil.
 - (c) Depth to impervious strata.

5. Drainage.

V. Climatology :

1. Temperature.
2. Precipitation.

VI. Crops :

1. Kind of crops.
2. Probable markets.
3. Transportation to markets.

VII. Value of lands :

1. Without irrigation.
2. Unimproved, but under ditch.
3. Improved and irrigated.

VIII. Water supply :

1. Source of supply :
 - (a) Discussion of stream.
 - (b) Discussion of drainage basin.
 - (c) Stream-flow measurements.
 - (d) Storage already developed.
 - (e) Other storage possibilities.
2. Rights in water :
 - (a) Amount and date of water filing.
 - (b) Prior rights, adjudicated and unadjudicated
3. Amount of water available for project.
4. Duty of water.
5. Amount of land that can be irrigated.

IX. Character of irrigation works :

1. Storage dam.
2. Location.
3. General description.
4. Type of dam, material, etc.
5. Outlet tunnel.
6. Area of reservoir.
7. Capacity of reservoir in acre-feet.
8. Diversion dam :
 - (a) Location.
 - (b) Type of dam, material, etc.
 - (c) Size of dam.
9. Pumping :
 - (a) Source, kind, and cost of power.
 - (b) Lift.

- (c) Motors:
 - (a) Number and kind.
 - (b) Capacity of each.
- (d) Pumps:
 - (a) Number and kind.
 - (b) Capacity of each.
- (e) Station equipment.
- (f) Transmission line.
- (g) Buildings.
- (h) Pipe lines:
 - (a) Kind, size, and capacity.
 - (b) Thickness of material.
 - (c) Length.
- (i) Receiving basins.

X. Canals:

- 1. Size.
- 2. Grade.
- 3. Capacity.
- 4. Slopes.
- 5. Wasteways.
- 6. Drops.
- 7. Lateral systems.
- 8. Flumes:
 - (a) Kind (wood, metal, or concrete).
 - (b) Size.
 - (c) Grade.
 - (d) Capacity.
 - (e) Carrier.
 - (f) Foundation.
 - (g) Description of construction.
- 9. Tunnels:
 - (a) Length.
 - (b) Size.
- 10. Pipes:
 - (a) Kind (wood, metal, or concrete).
 - (b) Size.
 - (c) Length.
 - (d) Grade.
 - (e) Capacity.
 - (f) Pressure boxes.
- 11. Gates:
 - (a) Headgates:
 - (a) Kind.
 - (b) Size.
 - (c) Capacity.
 - (d) Number.
 - (e) Controlling device.
 - (b) Lateral gates: Kind, etc.
- 12. Miscellaneous:
 - (a) Bridges.
 - (b) Trestles.
 - (c) Riprapping.
 - (d) Protection.

- XI. Cost of construction :
 - 1. Detailed estimate.
 - 2. Bases for estimate.
- XII. Present status of project :
 - 1. Work completed :
 - (a) Amount.
 - (b) Character.
 - (c) Criticisms.
- XIII. Revenue :
 - 1. Water rights.
 - 2. Number of acres covered.
 - 3. Number of acres sold.
 - 4. Town sites.
 - 5. State contract.
 - 6. Settlers' contract.
- XIV. Appendixes :
 - 1. Maps.
 - 2. Geologic sheets.
 - 3. Photographs.
 - 4. Precipitation records.
 - 5. Stream-flow records.
- XV. Suggestions.
 - Recommendations.
 - Conclusions.
 - Extensions.

To determine whether or not an area of land is commercially feasible of reclamation by irrigation the following matters require especially careful study :

- Available water supply.
- Present utilization of water for irrigation.
- Duty of water.
- Character of lands to be irrigated.
- Crops.
- Character of irrigation works.

AVAILABLE WATER SUPPLY.

To determine the available water supply a careful investigation is made of the streams from which the water is to be diverted. A study is made of all stream-flow measurements, and if records of daily discharge are available for a number of years, hydrographs are prepared showing graphically the daily fluctuations of the stream. On these hydrographs a line may be drawn representing the equivalent of prior rights. This done, the unutilized flow may be readily determined. Where irrigation has been practiced for a number of years, these hydrographs may show clearly that the normal flow during the irrigation season is already appropriated and that the unutilized flow occurs during the winter and during flood stages. To utilize fully the run-off from the streams under such conditions reservoirs must be constructed to store the water that is now wasted.

The study of available water supply therefore involves an investigation of the possibilities of storage. Unless information is available from private surveys, a reconnaissance examination is made of the drainage area for the purpose of locating storage sites. The methods followed are merely approximate and do not differ from those used in reconnaissance power surveys.

If no actual records are available showing the discharge of the stream, it is necessary to establish gaging stations at once and make a careful study of the drainage area and records of precipitation. If reliable maps are available from which the area of the drainage basin can be measured, and records are available showing the average precipitation on the basin, it is then possible to figure roughly the probable run-off. This method of determining the available water supply is unsafe and is used only where no records of discharge are available.

After determining the gross run-off from the basin the unutilized flow or the water available for the reclamation of new lands is determined by deducting the amount of water required to satisfy prior appropriators.

PRESENT UTILIZATION OF WATER FOR IRRIGATION.

Mention has already been made of the necessity for allowing for prior water rights in determining the amount of land that can be successfully irrigated from any stream. Irrigation systems already installed at the time of the examination furnish one of the most troublesome problems the engineer has to investigate. Under the law, as usually interpreted in the West, the water is public property, permission for its use being granted by the State, and wherever lands are classified for irrigation in the West it is nearly always true that the State has granted prior rights to the use of the water. In the earlier days of irrigation these rights were granted with the utmost liberality, without much regard for the amount of water actually flowing in a stream. It is therefore common to find that these prior rights exceed in aggregate amount the volume of water carried by the stream during irrigation seasons. This condition has been recognized by persons desiring to use water from such streams, and many of them have secured rights to use the flood waters which flow in the stream channels at periods of the year when irrigation is not practiced. Such utilization is dependent, of course, on the construction of storage reservoirs. Thus it may occur that, however well adapted for agriculture a piece of public land may be, on superficial examination there appears to be no available water for its reclamation. It is necessary for the engineer to bear in mind the liberality with which prior rights have been conferred and to examine

the records for the purpose of determining what proportion of the water so granted can be beneficially used for irrigation. Such a study involves a determination of the duty of water, a subject which is discussed below. It is clear, however, that the determination of beneficial use involves an examination of the reservoirs, headworks, canals, and ditches, and the amount of lands embraced in irrigation systems under operation, and this is frequently a most difficult matter. It is the rule rather than the exception that the irrigator uses more water than is necessary for the growth and maturity of his crops; indeed, his use of water is not uncommonly so extravagant that the agricultural value of his land is greatly damaged. On few of the irrigation systems of the West, especially the older ones, has any record of the amount of water used been collected or preserved or the capacity of the irrigation canals been determined. This capacity may be variable, depending largely on the care with which the canals are maintained. Thus the engineer is obliged to investigate thoroughly all the working features of the systems already installed, so that he may make a report as to the actual amount of water necessary and thereby determine how much if any is available for the irrigation of new lands. Water-right matters are usually complicated and a proper study of them requires some working knowledge of the water laws and the decisions relating thereto. Although in many of the Western States the water laws are similar, they differ in some respects and some of the differences are very wide. To cover all the necessary points the engineer must examine into the grants and adjudications at the county or State offices where such matters are on record. Closely connected with this study of water laws is the observation and possibly the measurement of flow in existing canals to determine seepage losses. Such losses frequently represent 50 per cent or more of the water that is diverted from the streams, and it is necessary to consider the question of preventing such losses so that the water may be applied to lands not under cultivation. Where extravagant use or unreasonable loss is discovered the question then arises whether that water may not be filed upon for the benefit of the new lands under consideration. The determination of this point usually requires adjudication either by the courts or by State officials appointed for this specific purpose.

DUTY OF WATER

The determination of the duty of water, or the amount of water necessary to irrigate a piece of arid land suitably, is another difficult task of the engineer. In some parts of the West the necessary amount of water has been determined by scientific study. Over the greater portion of this region, however, the amount has been determined

largely by experience, so-called, and has usually been greater than is necessary. Frequently the lower limit has been determined in dry seasons when the supply of water was meager. Therefore the duty of water is susceptible of a very flexible interpretation. On each irrigation project there is a generally accepted idea of the amount necessary, and whether a larger or smaller amount than this is delivered by the canals is rarely determined. As a rule, however, the discriminating engineer can, by examining all the evidence, fix upon an approximate standard that may be considered reasonable, and unless that standard approaches too closely the total amount of water available adjustment is comparatively easy. Determination of the duty of water is, after all, an agricultural problem, some crops requiring more than others on the same land and different kinds of soils requiring different amounts for the same crops. Having determined this amount, the engineer then measures or estimates the losses which occur in transmission through canals and other conduits from the source of supply to the cultivated fields, for duty of water is, unless otherwise specified, referred to the field itself. This amount is sometimes called the net duty. To the amount required for actual application to the crops must be added that lost by seepage and by evaporation, and the farther the supply from the place of utilization the greater the amount which must be allowed for such losses. It is necessary also to consider losses in the storage reservoirs, especially the loss due to evaporation. Having summed up all these items and having previously determined the total supply available, the engineer can then determine how much is available for new lands. To this quantity is applied the duty previously determined, allowance being made for the prospective losses in the conduits that will carry the water to the new land. The result of this computation will show the amount of new land that can be irrigated.

CHARACTER OF LAND TO BE IRRIGATED.

The elements in the investigation of the character of the lands to be irrigated include topography, geology, character and depth of soil, and general drainage conditions. These are partly engineering and partly agricultural factors, but the engineer must take them all into consideration, because it is apparent that, with a given prospective cost of irrigation, a project would be feasible if the soil and physical conditions were of one kind and not feasible if those conditions were of another kind. The climate is another essential factor, and a study must also be made of the kind of crops adapted to the particular locality. It is apparent that a greater investment can be made for irrigation in a region adapted to citrus fruits than in one where, on account of climate, soil, or altitude, hay is the principal possible commodity. The determination of these points by the engi-

neer rests largely on his general knowledge of related conditions and on the experience that has been gained by the people in the region. The transportation facilities and the market are subject to change and should usually be considered merely to determine whether present or future development is desirable. Transportation facilities will, under ordinary conditions, be provided in response to production, and market is a feature which, in the long run and under the present conditions of rapid growth and consumption in this country, will ultimately offer few difficulties.

CHARACTER OF IRRIGATION WORKS.

Having reached a favorable determination as to water supply, duty of water, and the economic features above set forth, the engineer must then investigate the character of irrigation works that are adapted to the physical conditions of the area. The character of such works depends entirely on the physical problems to be met. It may be necessary to construct storage reservoirs in order to utilize the highest possible proportion of the available water. On the other hand, the source of supply may be a very large stream, having a capacity sufficient to furnish all the water required for practicable irrigation in the entire region, and the studies are then confined to the determination of suitable diversion sites and canal routes reaching from the headworks to the lands to be irrigated. As in the case of reconnaissance power surveys, no final locations are determined by the engineer, it being considered preferable to leave such matters of detail to those who may in the future develop the project. The location of the headworks and of reservoirs and the routes, lengths, and capacities of canals can be determined approximately by field investigation of the type herein described, and while the results may be inaccurate for purposes of final location and development, they are sufficient to afford information suitable for departmental action. The public lands located in reservoir sites or along the courses of prospective conduits are carefully considered by the engineer with respect to their relation to the ultimate problem under consideration.

METHODS OF CLASSIFICATION.

PROCEDURE UNDER THE CAREY ACT.

In the administration of the Carey Act and its amendments classification of lands with respect to irrigability is a necessary incident, for under the conditions of this act the land granted must be non-mineral, desert, and irrigable. The first step in the present procedure is the withdrawal of lands under the act of March 15, 1910 (36 Stat., 237), at the solicitation of the State in which the lands are

situated. This is essentially a withdrawal for the purpose of classification, and the area withdrawn may be far in excess of that eventually constituting the irrigable area of the project. The withdrawal is made on the assumption that the area includes some land susceptible of irrigation under the Carey Act, but investigation may show this not to be the case. During the period of withdrawal, which is limited to one year, the promoter of the project has opportunity to investigate the area, plan the details of the project, and make a reliable classification as to irrigability without fear of alienation of the lands and resulting interference with the successful conduct of the project. In case such investigations and a request by the State for segregation are not made, the land is restored to the public domain without classification. If, on the other hand, the plans for the project are perfected and application for segregation is made, the lands listed in the application are further reserved until action is taken on the case, and the remainder of the withdrawn lands are restored to the public domain and may thereafter be assumed to be nonirrigable. The regulations require that the application for segregation shall include full data to show that the land is nonmineral and desert land and is irrigable and that the project is feasible. A field investigation is made by the General Land Office and the case is referred to the Geological Survey for report. A careful analysis of the water supply of the project is then made by the Survey, and sufficient investigation of probable costs and returns is made to show whether the reclamation and settlement can probably be accomplished at a cost warranted by the value of the reclaimed lands. If the existing data relative to the amount of water available for the project are insufficient to warrant a reasonably definite conclusion as to the area that can probably be irrigated, a hydraulic engineer of the Geological Survey may be called upon to supplement them by stream gagings and such other determinations as seem advisable. When all the data are considered, an estimate of the allowable area is prepared and a definite report and recommendation on the case are made. Final adjustment of the area to be segregated and of the terms of the contract between the Secretary of the Interior and the State devolves upon the General Land Office.

The approval of the segregation list under present departmental practice is in effect a fairly reliable classification of the land as non-mineral, desert, and irrigable. The aim of the work as now conducted is to safeguard the welfare of prospective settlers, the necessary investment of capital, and the interest of the Government. Some attention is being paid also to construction and settlement on Carey Act projects. When data obtained after the segregation is made indicate that the area included in a project exceeds the land

that can be successfully irrigated, or when it is learned that constructing companies are attempting to increase the area of the project by selling water rights to owners of private lands and thus depriving the segregated lands of a portion of the water supply necessary for their complete reclamation, conferences are held with State authorities and prompt measures are taken to insure the protection of the settlers. It is hoped by such means to avoid the disastrous results that have heretofore too often attended operation under the Carey Act, to eliminate speculation, so far as possible, and to insure, so far as the department has the power, that the settler who seeks a home on segregated lands will receive a sufficient area of land with a satisfactory water right at a reasonable cost.

IRRIGATION RESERVOIR SITES.

Withdrawals of sites for irrigation reservoirs under the acts of June 25, 1910 (36 Stat., 847), and August 24, 1912 (37 Stat., 497), are made in the same way as withdrawals of power sites whenever the investigations of the Geological Survey indicate that feasible locations exist. Such withdrawals are made in the interest of bona fide development and to withhold from adverse possession reservoirs required in connection with large irrigation projects, both public and private. Modifications of the withdrawals to permit occupation and use of the sites under the applicable right of way acts are made when the development is warranted and applications for modification are made by responsible parties.

PROCEDURE UNDER THE ENLARGED-HOMESTEAD ACT.

The classification of lands under the enlarged-homestead acts also devolves upon the Geological Survey, the Director having been instructed by the Secretary of the Interior to make recommendations of lands suitable for designation thereunder. Nearly 193,000,000 acres of land have been designated in the States to which the provisions of the acts apply. Of this area, approximately 157,000,000 acres were designated within three months after the passage of the earlier acts. This result was achieved in part by the use of topographic maps, the accumulation of 35 years of work, in connection with a large number of which unpublished land-classification sheets were on file; in part by the application of available data on rainfall, run-off, and stream flow; in part by consultation with the Reclamation Service; and in part by the cooperation of the several State engineers. In spite of the uncertainty incident to rapid work covering large areas, later information has shown that these designations were in general properly made. The cancellations of erroneous designations amount in the aggregate to about 615,000 acres, or less

than 0.4 per cent of the early designations. Since the first general designations were made numerous requests for the designation of additional areas have been received, and the work incident to the designation of lands under the enlarged-homestead acts now consists largely of the consideration of such requests, with office and field studies to determine whether the lands involved may properly be designated. The office studies include investigation of township plats, topographic maps, records of irrigation projects, rainfall and stream-flow data, and other sources of information from which a conclusion as to the suitability of the land for designation may be reached. In case field examination is made, the results are used in the office studies preceding designation.

Not all nonirrigable lands, however, may properly be designated, for it would obviously be useless to designate lands that could not be entered under the acts. Unsurveyed lands are not designated and newly surveyed lands are, by departmental order, withheld from designation until six months after the filing of the approved plats of survey in the local land office. Patented lands are, of course, not lands of the United States and are therefore eliminated from proposed designation. Lands on which there is sufficient rainfall for the production of ordinary crops without recourse to unusual methods of cultivation are not designated. Lands on which there is merchantable timber or which contain valuable minerals other than coal (in Utah coal, oil, or gas) are not properly subject to designation. Coal lands and in Utah coal, oil, or gas lands may be designated and entered subject to the terms of the acts providing for agricultural entries of the surface rights on such lands. Lands included in withdrawals or reservations of any kind or in Carey Act segregations are not properly subject to designation. Lands entered and in process of acquisition under the public-land laws may be designated if otherwise subject to the act, but lands included in subsisting entries under the desert-land act, being *prima facie* irrigable lands, are not properly subject to designation. Lands including sections granted to States as school lands are not designated unless they are excepted from the school grant.

Although no form of petition is specified for the use of those requesting the designation of lands under the enlarged-homestead acts, it is desired, in order that the Survey may have such information concerning the character of the land as the petitioner can supply, that such petitions be made on the usual form of application for entry of such lands, wherein the applicant sets forth under oath statements as to important features of the character of the land. Where this form is not used an affidavit setting forth essentially the same information is requested of the petitioner.

Orders of designation originating in the Geological Survey have been serially numbered both with general and State numbers. The form of letter and order used is here shown:

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
Washington, January 6, 1913.

The honorable the SECRETARY OF THE INTERIOR.

SIR: The following areas of land to which the enlarged-homestead act of February 19, 1909 (35 Stat., 639), as construed by the department, is applicable are, in my opinion, not susceptible of successful irrigation at a reasonable cost from any known source of water supply, and I therefore recommend their designation under the said act:

ENLARGED-HOMESTEAD DESIGNATION No. 210.

Montana No. 50.

Montana meridian, Montana.

T. 9 N., R. 7 E., sec. 22, lots 2, 3, 4, and 5. NW. $\frac{1}{4}$ of SE. $\frac{1}{4}$.
[Here follows remainder of land description.]

The above-listed lands will be enterable under the provisions of the enlarged-homestead act in so far as they may be vacant, public, nontimbered, and nonmineral and unaffected by any special provision of law, withdrawal, or reservation inconsistent with the provisions of said act. The surface of coal lands may, however, be entered subject to the reservation of the coal to the Government.

The area included in this designation is approximately 1,485 acres. None of the lands listed above are withdrawn in oil, phosphate, or power-site reserves.

Very respectfully,

GEO. OTIS SMITH,
Director.

Approved January 28, 1913, and referred to the General Land Office to become effective February 27, 1913.

SAMUEL ADAMS,
First Assistant Secretary.

The office record of the Survey relating to enlarged-homestead designations consists of State maps on which the designated lands are platted, a file of orders of designation arranged by serial numbers, a file of minutes similarly arranged showing the data on which the designation is based, and township cards on which are platted the designated areas. Cancellations are similarly recorded and filed, all designations and cancellations affecting any township, however, being shown on a single township card.

withdrawal of public watering places under the authority conferred by the acts of June 25, 1910 (36 Stat., 847), and August 24, 1912 (37 Stat., 497), has been sanctioned by the President. The first withdrawal for this purpose was approved by him on March 29, 1912. The effect of withdrawals of this character is to prevent alienation of the lands pending legislation governing their use under public control, but the use of the watering places by all is meantime possible under such conditions that no user can acquire the right of permanent exclusive occupation.

These withdrawals are based upon field investigation by members of the Geological Survey and some of them on reports of General Land Office inspectors. Careful consideration is given to the relation of the watering place to the surrounding range and its value in connection with grazing on the public lands. Agricultural lands susceptible of successful cultivation have been excluded from withdrawal except in regions where most of the watering places have passed into private ownership and it becomes imperative to reserve water for stock, even at the expense of settlement.

MUNICIPAL WATER SUPPLY.

An incidental classification of lands as valuable for domestic water supply arises through right of way applications for municipal systems. In general, where sources of water supply are sought for municipal purposes their value therefor far exceeds their value for power or irrigation. Approval of such right of way applications therefore amounts to a definite classification of the lands affected. The lands may be used for reservoirs, conduits, stream protection, or any other purpose relating to municipal water supply.

Such right of way applications are referred to the Geological Survey for report. In view of the relatively high value of water for municipal supply, the question whether the application provides for the highest use is seldom considered. The most troublesome question is to determine whether the application is really made for municipal purposes. If the application is made by a municipality this question is readily answered, but if a private water company makes the application it may be difficult to determine whether the purpose is private or municipal. A strict showing of municipal authorization to the private company is required in such cases and constitutes the chief criterion for classification.

Lands embraced in permits for municipal water supply are withdrawn and reserved in order that occupation in the interests of the municipality may be suitably protected.

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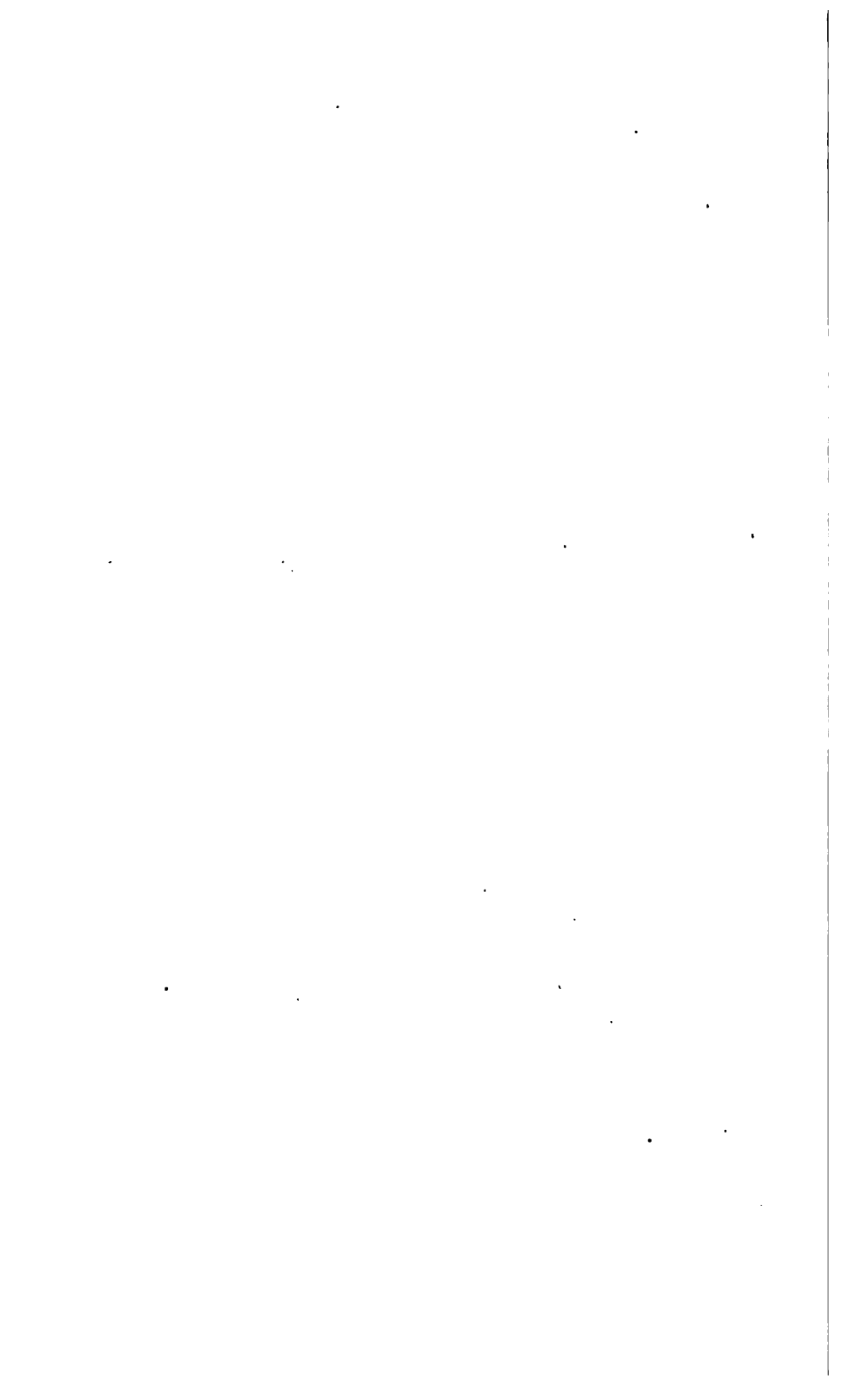
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DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

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BULLETIN 538

A GEOLOGIC RECONNAISSANCE
OF THE
CIRCLE QUADRANGLE, ALASKA

BY

L. M. PRINDLE



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PREFACE.

By ALFRED H. BROOKS.

Systematic geologic surveys and investigations of the mineral resources of the Yukon-Tanana region were begun in 1903 and were carried on in each succeeding year until 1911. For the first five years the work consisted of geologic exploration without base maps and afforded little opportunity for areal mapping. Meanwhile, however, topographic surveys of the region were being made, and during the last four years the geologist has usually had a base map on which to outline his stratigraphic units and has been able to make his investigations more detailed. For the most part, however, the work has been of a reconnaissance character except near Fairbanks, where a detailed geologic map covering about 436 square miles was made; elsewhere the results have warranted the preparation of very general geologic maps only. While these investigations were going on many reports covering the subject of mineral resources at some length and presenting geologic data were being published (see pp. 10-11), and it seemed best to defer the publication of the geologic reconnaissance maps until a large part of the field had been covered, thus permitting the correlation of the results obtained in the different districts.

The unit of publication for these maps is a quadrangle including 4° of longitude and 2° of latitude. The quadrangles mapped, named from east to west, are the Fortymile,¹ Circle, Fairbanks, and Rampart, all of which have, for the most part, been both geologically and topographically surveyed. A topographic base map for each quadrangle has been issued, and an account of the geology and mineral resources of the Fortymile quadrangle² has been published.

The geologic reconnaissance mapping of the Fairbanks quadrangle was completed in 1910, and the results are now in course of publication.³ In 1911 the reconnaissance of both the Circle and Rampart⁴

¹ The Fortymile quadrangle, which is adjacent to the boundary, includes only 1° of longitude and 1° of latitude.

² The Fortymile quadrangle, Yukon-Tanana region, Alaska, by L. M. Prindle: Bull. U. S. Geol. Survey No. 375, 1909.

³ Prindle, L. M., Geologic reconnaissance of the Fairbanks quadrangle: Bull. U. S. Geol. Survey No. 525, 1913.

⁴ Eakin, H. M., Geologic reconnaissance of a part of the Rampart quadrangle, Alaska: Bull. U. S. Geol. Survey No. 535, 1913.

quadrangles was completed. None of the quadrangles were entirely covered by geologic mapping, but as the blank areas could be filled in only at the expense of much time and money it seemed best to issue the maps in incomplete form.

No one not familiar with the Yukon-Tanana region can realize the difficulties that are encountered in its geologic mapping. Though the region is now well known, much of it is so inaccessible that it can be investigated geologically only by a well-equipped expedition organized to work a hundred miles or more from a base of supplies. Inaccessibility, however, is the least of the difficulties. The complexity of the geology and the absence over large areas of bedrock exposures have made the geologic work extremely arduous. Most of the surveys have been made by expeditions moving rapidly and having little opportunity for exhaustive study of any particular locality. The geologist has been forced to seek his facts along routes of travel determined by physical obstacles, shortness of field season, etc., instead of being able to follow up special problems that might help to unravel the complexities of stratigraphy. Working under these conditions Mr. Prindle and his assistants have in less than a decade outlined the larger stratigraphic units in an area of more than 40,000 square miles and have thus paved the way for the detailed investigations which must be undertaken before a full knowledge of the sequence and structure of the rocks can be gained. The results are of value not only to the science of geology but also to the prospector and miner, to whom they supply a knowledge of the distribution and association of the mineral deposits. With the publication of this series of reports on the Yukon-Tanana region the first epoch of the geologic survey of the region will be closed. The completion of the work will be followed, as soon as circumstances will permit, by more detailed examinations of especially selected areas.

A GEOLOGIC RECONNAISSANCE OF THE CIRCLE QUADRANGLE, ALASKA.

By L. M. PRINDLE.

INTRODUCTION.

The Yukon-Tanana region comprises an area of about 50,000 square miles lying between Yukon and Tanana rivers west of the international boundary. For purposes of mapping and description this area has been divided into the Fortymile, Circle, Fairbanks, and Rampart quadrangles.

The Circle quadrangle (fig. 1) contains about 17,000 square miles and includes several districts that have been productive of placer

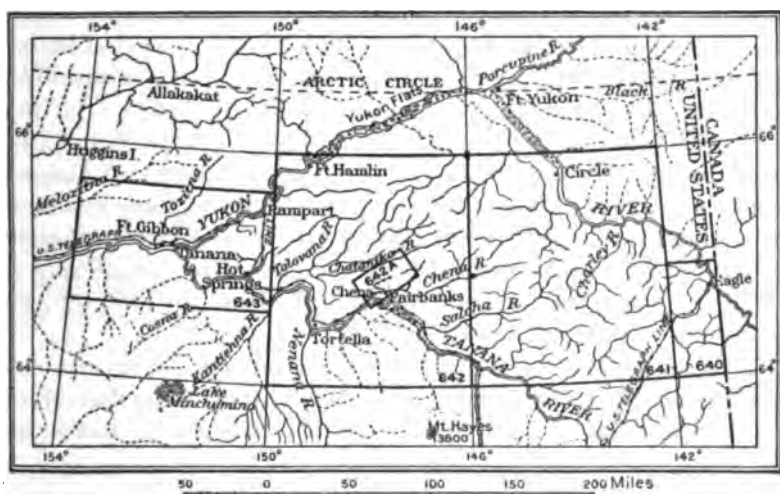


FIGURE 1.—Index map showing location of Circle quadrangle (No. 641).

gold. The most important of these, the Birch Creek district, was the site of some of the earliest prospecting in the interior of Alaska; and the abundant results of the discoveries of gold in it in 1893 led to the exploration of adjacent areas accessible from the Yukon and of small valleys tributary to the Yukon above Circle, including Woodchopper, Coal, and Washington creeks. In the eastern part of the quadrangle some placer ground was discovered in the upper valley of the Seventy-mile and on the North Fork of Fortymile. The establishment of a

Government telegraph line and stations and the construction of a trail from Eagle by way of North Fork of Fortymile and Goodpaster rivers to the Tanana rendered the eastern and southern portions more accessible. The discoveries of gold in the Fairbanks district in 1902 and the subsequent rapid development of that region afforded new bases of supply for prospectors and made large areas in the western part of the quadrangle comparatively easy of access.

The rapidly growing importance of the gold-placer districts in Alaska led to topographic and geologic work by the Government. Spurr¹ visited the Birch Creek district in 1895. Brooks² explored Tanana River, which sweeps the southwest corner of the quadrangle, in 1898. Collier³ studied the geology of the northeastern portion of the quadrangle adjacent to Yukon River in 1902. Prindle spent a portion of the field seasons of 1903, 1904, and 1905 and the whole of the field season of 1911 in the area of the Circle quadrangle. Stone⁴ traversed the northwestern portion of the quadrangle in 1905. Brooks and Kindle⁵ studied the geology of the northeast portion adjacent to the Yukon in 1906.

The geologic work in 1903, 1904, and 1905 was done without a map. Rough foot traverses were made upon which the geologic results were assembled. The topographic map of the Circle quadrangle, the result of surveys made in 1903, 1904, 1905, and 1908, was available for the geologic work of 1911, and upon this map have been assembled for this report the available geologic data, both published and unpublished. The fact must be emphasized that in comparison with the size of the area the amount of work done is small and that the results are in very large degree only preliminary. Some of these results have already been published, and in this report free use has been made of these and of all Survey work in this area. In the reconnaissance work of 1904 the writer was assisted by Frank L. Hess, in 1905 by Adolph Knopf, and in 1911 by J. B. Mertie, jr.

The following list of publications of the Geological Survey contains not only the names of reports bearing upon the area immediately under discussion but also of those on the adjacent areas in the Yukon basin.

*The coal resources of the Yukon, Alaska, by A. J. Collier. Bulletin 218, 1903, 71 pp.

*The gold placers of the Fortymile, Birch Creek, and Fairbanks regions, by L. M. Prindle. Bulletin 251, 1905, 89 pp.

Yukon placer fields, by L. M. Prindle. In Bulletin 284, 1906, pp. 109-131.

Reconnaissance from Circle to Fort Hamlin, by R. W. Stone. In Bulletin 284, 1906, pp. 128-131.

*Survey stock exhausted; may be purchased from the Superintendent of Documents, Washington, D. C., or may be seen at most public libraries.

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² Brooks, A. H., *A reconnaissance in the White and Tanana river basins, Alaska*, in 1898: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1900, pp. 425-494.

³ Collier, A. J., *The coal resources of the Yukon, Alaska*: Bull. U. S. Geol. Survey No. 218, 1903.

⁴ Stone, R. W., Bull. U. S. Geol. Survey No. 284, 1906, pp. 128-131.

⁵ Brooks, A. H., and Kindle, E. M., Bull. Geol. Soc. America, vol. 19, 1908, pp. 255-314.

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- *Water supply of the Yukon-Tanana region, 1907-8, by C. C. Covert and C. E. Ellsworth. In Bulletin 379, 1909, pp. 201-228.
- *Gold placers of the Ruby Creek district, by A. G. Maddren. In Bulletin 379, 1909, pp. 229-233.
- *Placers of the Gold Hill district, by A. G. Maddren. In Bulletin 379, 1909, pp. 234-237.
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- Sketch of the geology of the northeastern part of the Fairbanks quadrangle, by L. M. Prindle. In Bulletin 442, 1910, pp. 203-209.
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- *Gold placers between Woodchopper and Fourth of July creeks. In Bulletin 520, 1911, pp. 201-210.

Topographic maps.

- Fortymile quadrangle; scale, 1:250,000; by E. C. Barnard. For sale at 10 cents a copy or \$3 for fifty.
- Fairbanks quadrangle; scale, 1:250,000; by T. G. Gerdine, D. C. Witherspoon, and R. B. Oliver. For sale at 50 cents a copy or \$15 for fifty.
- Rampart quadrangle; scale, 1:250,000; by D. C. Witherspoon and R. B. Oliver. For sale at 20 cents a copy or \$6 for fifty.

* Survey stock exhausted; may be purchased from the Superintendent of Documents, Washington, D. C., or may be seen at most public libraries.

Fairbanks special map; scale, 1:62,500; by T. G. Gerdine and R. H. Sargent. For sale at 20 cents a copy or \$6 for fifty.

*Yukon-Tanana region, reconnaissance map; scale, 1:625,000; by T. G. Gerdine. Contained in Bulletin 251, 1905. Not published separately.

*Fairbanks and Birch Creek districts, reconnaissance maps; scale, 1:250,000; by T. G. Gerdine. Contained in Bulletin 251, 1905. Not issued separately.

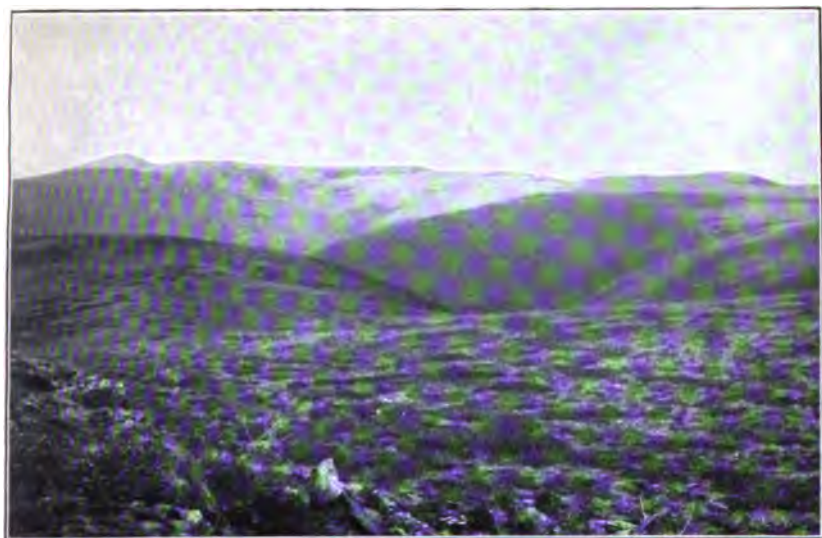
Circle quadrangle, Yukon-Tanana region; scale, 1:250,000; by D. C. Witherspoon. Contained in Bulletin 295. For sale at 50 cents a copy.

GEOGRAPHY OF THE YUKON-TANANA REGION.

The portion of the central plateau province of Alaska included between Yukon and Tanana rivers is similar in its major features to the related portions north and south of those streams. It is an upland characterized by a general level above which rise many ridges and isolated domes and below which a minutely ramifying drainage system has deeply intrenched itself. In the eastern portion the general surface attains its greatest elevation, rising to about 4,000 feet above sea level. The northern edge of the upland overlooking the Yukon Valley rises to about 3,000 feet and the southern edge overlooking the Tanana Valley to about 2,000 feet. The elevation of the Yukon Valley is about 800 feet in the extreme eastern portion of the region and about 400 feet at the mouth of the Tanana, in the extreme western portion. The highest domes that rise above the general level attain altitudes of about 5,000 feet and several mountain groups and ridges stand from 5,000 feet to over 6,500 feet above sea level. Among these are the Glacier Mountains in the vicinity of Eagle, the mountainous country of the Charley River and Goodpaster regions, the White Mountains in the Beaver Creek region, and the group of hills of steep relief near Rampart. Most of these areas of high relief are due to the fact that the rocks composing them are mainly igneous and are more resistant to weathering than the rocks of adjacent regions.

The drainage of the region belongs entirely to Yukon and Tanana rivers. The valley of the Yukon in this region is made up of an upper narrow canyon-like portion, a wide flat lowland known as the Yukon Flats, and a lower canyon-like portion extending from the lower end of the flats to the mouth of the Tanana. Tanana River is close against the southern edge of the upland, and the Tanana Flats, similar to the Yukon Flats, separate the Yukon-Tanana upland from the similar upland flanking the northern base of the Alaska Range. The tributaries of the two rivers in the Yukon-Tanana region are not separated by any well-defined divide but are most intimately intertwined. In general, the interstream or upland areas predominate over the stream or lowland areas. The valleys are comparatively narrow and canyon-like, and the lowlands are not extensively developed except near Yukon and Tanana rivers and especially near their confluence. In general, then, the Yukon-Tanana region is a compact body of upland deeply dissected by comparatively narrow stream systems.

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A. SCHIST RIDGE BETWEEN NORTH FORK OF BIRCH CREEK AND CROOKED CREEK.

Altitude about 3,400 feet.



B. FLAT-TOPPED RIDGE OF QUARTZITIC SCHIST BETWEEN DAVIS AND POKER CREEKS.

Altitude about 3,800 feet



A. OPEN VALLEY, TRIBUTARY OF CHARLEY RIVER.



B. NARROW VALLEY, HEAD OF CHENA RIVER.

GEOGRAPHY OF THE CIRCLE QUADRANGLE.

LOCATION AND EXTENT.

The Circle quadrangle lies between meridians 142° and 146° west longitude and parallels 64° and 66° north latitude. It is about 140 miles long from north to south, about 120 miles wide, and has an area of about 17,000 square miles. The northeast corner of the quadrangle, including about 3,000 square miles lying north of Yukon River, is unmapped, has not been traversed by Survey parties, and is not included in this discussion.

RELIEF.

The surface of the Circle quadrangle is the most diversified in the Yukon-Tanana region. It is separable into two main topographic subdivisions—the Tanana lowland and the upland, which is bounded on the north by the Yukon Flats.

The upper end of the Tanana lowland, which comprises a comparatively small area in the southwest corner of the Circle quadrangle, has an elevation above sea level at the mouth of Delta River of 940 feet. Delta and Tanana rivers, whose flats constitute most of the lowland, are distributed in many interlacing channels in which the water flows swiftly between gravel bars. The valleys of the tributaries of the Tanana from the north widen sharply as they approach the main stream and finally merge with the Tanana lowland. Long ridges from the upland terminate abruptly at Tanana River.

The Circle quadrangle contains a greater proportion of upland than any other quadrangle in the Yukon-Tanana region. It also contains the highest points in the region, among these being two peaks in a high ridge near the head of Charley River (6,284 and 6,340 feet above sea level) and a peak at the head of Healy River (6,515 feet, the highest elevation in the region).

The upland has an extreme elevation of about 4,000 feet in the central part of the quadrangle near the headwaters of Fortymile, Charley, and Goodpaster rivers. This general level is strikingly maintained in the long flat-topped spurs that extend both north and south from the divide separating Goodpaster and Fortymile waters, and it is traceable to the vicinity of both Yukon and Tanana rivers, where its elevation is about 3,000 feet above sea level. The uniformity of level is shown in Plate III, *A*. For comparison the same feature is shown in Plate III, *B*, from a point more than 100 miles farther east.

In the vicinity of the Yukon in the northeastern part of the quadrangle a belt 10 to 25 miles wide, lying 2,500 to 2,000 feet above sea level, contrasts with the higher, rougher country to the south and is characterized by more uniform and more even-topped ridges that continue to the Yukon.

The ridges rising above the general level are most conspicuous. The highest, so far as observed, are composed of igneous rocks and owe their pronounced relief to their resistance to weathering. As igneous rocks form one-third or more of the total area of the quadrangle, ridges due to their influence predominate.

The ridges have no general trend. They are bulky forms, many of which are surmounted by narrow, saw-tooth ridge crests culminating in precipitous peaks. The steep ridge slopes are strewn with masses of granitic blocks, which in many places assume a more or less lobelike arrangement. On some ridges the granite has weathered into grotesque forms, which at a distance resemble monuments and buildings. Isolated domes are common, rising from a few hundred to 1,000 feet or more above the general level. Like the ridges, they owe their existence to the resistance to weathering of the rocks composing them.

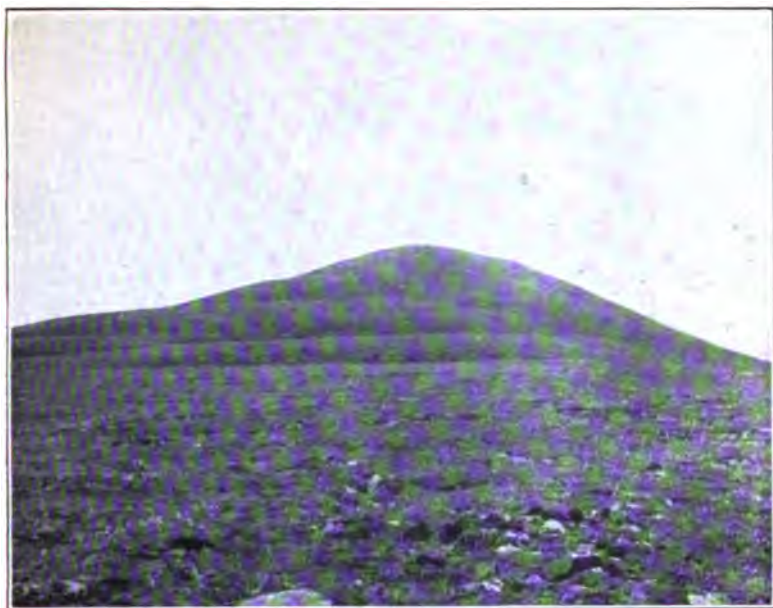
DRAINAGE.

The valleys are very uniform. Similar streams head at about the same level, are intrenched to about the same depth, have approximately the same grade, and carry about the same amount of water. These facts have an important bearing on hydraulic development, limiting the use of the streams for power. Most of the valleys are narrow, and the total amount of open valley land is small and is confined to the immediate vicinity of Yukon and Tanana rivers.

The most important tributaries of the Yukon are Birch Creek, Charley River, and Fortymile River. These streams are all formed of many large and widely divergent tributaries which drain widely separated areas, and the main trunk streams which they finally form by their union are comparatively short. Their upper valleys are for the most part open and are characterized by flats of considerable extent, which are especially well developed in the upper valley of Charley River. The valleys of the main trunks before the streams leave the upland and enter the valley of the Yukon are narrow and canyon-like. (See Pl. VI, A.)

The most important tributaries of the Tanana are Chena, Salcha, and Goodpaster rivers. These streams flow in more or less parallel courses and differ from the tributaries of the Yukon in consisting each of a long main stream with subordinate branches entering from either side. Their valleys are comparatively narrow except in the immediate vicinity of Tanana River, and most of them become narrower headward, merging into the deeply intrenched, canyon-like valleys of the headwaters. The head of Salcha River is an exception; owing to the slow process of cutting across the granite area at West Point its upper valley has become open.

In following the very irregular and ill-defined drainage parting between Yukon and Tanana rivers the contrast between the open valleys of the head of the Yukon drainage and the canyon-like



A. BENCH IN SCHIST 4,000 FEET ABOVE SEA LEVEL.



B. BENCH 500 FEET ABOVE SEVENTYMILE CREEK.



A. CANYON OF FORTYMILE CREEK 500 FEET BELOW THE LEVEL OF THE OLD VALLEY.



B. ARTIFICIAL CUT-OFF IN SCHIST AT THE "KINK," NORTH FORK OF FORTYMILE RIVER

beginnings of the Tanana drainage is found to be very general and very striking. (See Pl. IV.)

Very many of the smaller valleys are unsymmetrical in cross section, having on one side a comparatively steep slope with the stream flowing close to its base and on the other side a long gentle slope rising gradually for 1,000 feet or more and merging with a gentle ridge slope. This feature is in most places independent of the geologic structure and is most common on the west side of the valley, where the sun has more influence than on the opposite side. The western slope is the first to get the influence of the morning sun and has consequently undergone more rapid weathering.

Benches are conspicuous in some of the valleys, notably in that of Seventymile River, along which a very prominent bench about a mile wide lies about 500 feet above the stream level (Pl. V, B). Other benches occur at lower levels, and the stream is now flowing in a bed limited by a sharp rock-cut bench whose height averages about 15 feet above the stream. Above the level of these benches, all of which are definitely related to the present stream system, are other benchlike flats, which lie on the slopes of the ridges to a height of about 4,000 feet or more above sea level. (See Pl. V, A.)

Incised meanders are common on some of the streams. A notable occurrence is on North Fork of Fortymile River near the eastern edge of the quadrangle, at a place called the Kink. North Fork meanders in a narrow rock-cut canyon about 600 feet below the benches which formed the old valley of the Fortymile. The meander forming the Kink is $2\frac{1}{2}$ miles long, but the distance across the neck, which is formed by a ridge of schist about 100 feet high, is only 100 feet. The narrowness of the barrier made it possible to blast a cut through it and to draw off the stream, draining the river bed for the whole $2\frac{1}{2}$ miles and facilitating prospecting. The entire stream now flows through the cut over a fall and rapids about 17 feet high (Pl. VI, B).

Some of the conditions affecting the development of the streams in the Circle quadrangle are unlike those prevailing in more temperate regions. Normally the ice of lakes and the larger rivers may freeze in winter to a thickness of 5 or 6 feet, but in spite of the extreme cold much water remains in circulation in the streams, and the thickness of the ice is often increased at the top by the breaking out of the water at some point higher upstream and the consequent flooding of the ice already formed. Repetitions of this process may result in a considerable thickening of the ice. Areas of ice, acres in extent and 10 feet or more in thickness, formed in this manner linger in the valleys of some of the streams throughout most of the summer. (Pl. VII, A.) The ice exercises a determining influence in the distribution of the water as spring begins. Erosion starts first along the margins of the mass and the water beneath the ice becomes rather evenly distributed over a more or less flat body of gravel, which

some places is packed nearly as smooth as a pavement. (See Pl. VII, *B*.) Lateral erosion is accelerated and flats several hundred feet wide and a mile or more in length may be formed. This process has been observed to be effective in many valleys and has undoubtedly been active in the production of the flats so characteristic of many streams.

Another influence that has modified the normal valley development has been the local glaciation described in more detail on pages 34-35. Cirques and U-shaped valleys have been formed and morainal material has been deposited and has to some extent modified the drainage.

CLIMATE.

TEMPERATURE.

The climate of the Yukon-Tanana region, though influenced in part by distance from the coast and altitude above sea level, is determined mainly by the latitude. Long, cold winters, short summers, and permanently frozen ground are among the main characteristics. Temperatures of 80° F. below zero and 90° or more above zero have been reported. The alluvial deposits are for the most part permanently frozen to great depths, some having been reported frozen for more than 300 feet below the surface. Ice freezes on deep, quiet water to a thickness of 5 to 6 feet.

The Yukon at Circle closes to navigation about the middle of October and opens again about the middle of May. At the level of the Yukon killing frosts seldom occur during June and July, but during the later half of May and early June and the later half of August they may be frequent.

PRECIPITATION.

The summers vary greatly in character. In some of them long periods of fine weather occur in June and July, and but little rain falls throughout the season. In others thunderstorms and rainy periods are frequent, and the total rainfall is comparatively heavy. In general, however, the area is semiarid and the total precipitation during the summer is less than 1 foot.

The following data on precipitation are abstracted from the report of Ellsworth and Parker.¹

Precipitation records for 1910 show that the rainfall at Fairbanks was about 15 per cent below the average from 1906 to 1910; at Fort Gibbon it was about 6 per cent below the average from 1904 to 1910; and at Fort Egbert it was about 2 per cent above the average from 1903 to 1910. At Rampart a precipitation of only 5.32 inches was recorded, which is lower than that of any other year since the beginning of records at that station, in 1905, and only about one-half the average for the last six years.

¹ Ellsworth, C. E., and Parker, G. L., Water supply of the Yukon-Tanana region, 1910: Bull. U. S. Geol. Survey, No. 480, 1911, pp. 176-178.



A. ICE-FILLED STREAM FLAT, GOODPASTURE RIVER.



B. GRAVEL FLAT BENEATH ICE, TRIBUTARY OF CHARLEY RIVER.

A comparison of the records of 1910 with those of 1909 shows a small decrease at Fairbanks and Fort Gibbon and a considerable increase at Fort Egbert. At Rampart the decrease was nearly 50 per cent from the precipitation of 1909.

Although there is a wide difference from month to month and from year to year in the rainfall at the several stations in the Yukon-Tanana region, the mean yearly precipitation at each station for the period covered by the records is uniformly close to the average of the means of all the stations. In other words, the records show no uniform difference in precipitation throughout this area.

The following table gives the monthly precipitation at all points in the Yukon-Tanana region where records have been kept subsequent to 1903. Such scattered records as were kept previous to 1903 have been compiled by Abbe.¹

Monthly precipitation, in inches, at stations in Yukon-Tanana region, 1903-1910.

[Rainfall or melted snow is given in the first line; snowfall in the second line.]

Station.	Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Central.....	1906	0.56 6.1	0.06 1.0	0.05 1.4	0.47 4.7	0.86 2.0	4.91 2.1	4.82 1.40	1.85	0.82	0.70 7.0	0.80 8.0	0.35 4.0	15.95 34.2
Do.....	1907	1.04 10.0	.42 4.0	2.57 4.0	.93 8.0	.57 1.5	2.21	1.40						
Circle.....	1906												.75	
Do.....	1907	1.02 8.5	.57 7.8	.28 3.25	.15 1.45	.29 .29	1.36 .20	2.79 .87	1.73	1.73			9.5 .63	
Do.....	1908	1.23 9.2	.25 2.5	.76 6.8	1.45 8.0	.29	.20	.87	1.08	2.21	.40 3.0	.75 8.5	1.11 11.2	10.00 61.2
Do.....	1909	.44 4.5	.47 5.2	.17 1.0	.75 3.0	.60	2.24	3.25	1.02					
Charity Creek.	1908				.11	.27	1.33	2.80	2.33	2.28	.20 3.0			
Cleary.....	1907						.84	2.55	2.88	3.82				
Eagle Creek.	1908								2.99					
Fairbanks.....	1904											1.10	2.00	
Do.....	1905	.92 9.1	.50 5.0	.06 .5	.20 2.0				2.03	.86		1.20 12.0	.60 5.1	
Do.....	1906	1.75 17.5	.37 3.7	.33 3.3	.10 1.0	.36	1.05	2.82	1.80	.25	.30 3.0	6.5 65	11.5 115	10.68 44.1
Do.....	1907	3.30 33.0	.86 8.6	2.42 24.2	.03 .3	.35	1.47	1.51	1.81	3.58	2.44 24.4	3.5 35	5.9 59	18.71 99.9
Do.....	1908	.42 4.2	.21 2.1	1.10 11.0	.8 .8	.52	.96	.73	.71	1.57	.47 4.7	.51 5.1	.65 6.5	7.96 26.2
Do.....	1909	.80 8.0	.08 .08	.05 .05	.66 .66	.38 .38	1.64 1.64	1.90 1.90	1.73 1.73	.39 .39	.80 .80	.52 .52	.80 8.0	9.85 9.85
Do.....	1910	.70 7.0	.14 1.4	.02 .02	.36 .36	.39 .39	2.16 2.16	1.46 1.46	1.69 1.69	1.91 1.91	.66 .66	.50 .50	.76 7.6	9.75 9.75
Faith Creek.	1907						1.87	3.00	2.97					
Fort Egbert.	1903	.58	.81	.54	.12	1.38	.57	2.40	.97	2.97				
Do.....	1905					1.33	1.95	1.82	2.72	3.38	2.95	.93	.68	
Do.....	1906		.14	2.19	.00	.54	.51	2.54	1.28	.01	1.71	.51	.07	
Do.....	1907	1.45 2.0	.21 2.0	0 0	.25 .15	.40 .55	1.89	1.48	1.98	1.45	1.12 13.0	.40 4.0	.31	10.94
Do.....	1908	.12 3.0	.25 2.5	.75 7.5	.10 1.0	1.02	2.16	2.47	1.02	1.46	.18 6.0	.82 8.0	1.09 11.0	11.46 38.0
Do.....	1909	.16 2.0	.07 1.0	.11 1.0	.34 2.0	.28	2.35	1.77	.95	.88	.81 11.7	.30 3.0		
Do.....	1910	.83 8.3	.01 .01	.53 5.3	.25 .25	.28	1.05	2.28	2.03	2.98	.66 6.6	.25 2.5	.30	12.08
Fort Gibbon.	1903	.37	.73	1.14	.23	.16	.38	1.76		.43	.22	.33	Tr.	
Do.....	1904	.08	.55	.35	.09	.22	.33	1.95	3.80	.35	.39	.07	.70	8.88
Do.....	1905	.37	.47	Tr.	.32	.84	1.50	4.90	3.02	.59	1.10	.18	13.79	
Do.....	1906	.65 6.0	.20 2.0	.30 3.0	Tr.	1.00					.50 5.0	.99 9.9	.27	
Do.....	1907	1.26 12.6		.53 5.0	0 0	.80		2.58	2.31	2.32	1.22 12.0	.03 1.5	.31	
Do.....	1908	.23 4.0	.26 6.0	.90 17.0	0 0	1.16		.96	1.13	1.60	.45 4.5	.08	.60	
Do.....	1909	.05 2.2	.10 5	.37	.39	1.51	.77	1.49	2.27	.90	.49 4.9	.46 4.6	.80	9.60
Do.....	1910	1.23	.08	.60	.28	.69	.57	1.79	2.26	.74	.38	.59		

¹ Abbe, Cleveland, Jr., Prof. Paper U. S. Geol. Survey No. 45, 1906, pp. 189-200.

Oct. 7 to 31.

18 GEOLOGIC RECONNAISSANCE OF THE CIRCLE QUADRANGLE.

Monthly precipitation, in inches, at stations in Yukon-Tanana region, 1903-1910—Con.

Station.	Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Hot Springs...	1909							1.76	3.19	.25	.44	1.10	2.26	
Do.....	1910	1.64	.08	.60	.30	.34	.76	2.16		1.32	4.4	11.0	22.6	
Kechumstuk.	1904	16.4	.3	6.0	2.0	3.4								
Do.....	1905	.90	.10	.05	.40	.20	1.58	.40	1.48	2.16	1.18	.26	.20	9.01
Do.....	1906	.36	.05	.05	.27	1.69	1.61	3.25	2.51	.51	.31	.29	.20	11.11
Do.....	1907	4.0	.5	1.0	.50						4.3	.5	3.0	18.3
Do.....	1908	12.0	.29	.27	Tr.	1.30	2.03	1.60	2.14	.49	.72	.40		
Do.....	1909	2.0	3.0	4.0		12.0				2.0	9.0	4.0		
Do.....	1910	0	0	.41	.40	1.78	1.77	2.30	2.22	1.35		.90	.20	
Do.....	1909	0	0	5.0	4.0							9.0	2.0	
Do.....	1909	0	.30	.10	.20	0	3.66	3.39						
Do.....	1909	0	.5	1.0		0								
Miller House.	1909							2.98	1.26	.60	.83	.30	.20	
Do.....	1910				.20		1.94	2.37	.30	1.03	4.0	8.0	3.0	
North Fork.	1905								1.61	1.86		.60	.20	
Do.....	1906	.70	.50	.10	.80	1.98	2.74	2.69	1.01	.72	.42	.55	.38	12.9
Do.....	1907	7.0	5.0	1.0	8.0						3.2	4.5	4.5	33.2
Do.....	1907	.69	.28	.27	Tr.	1.34	1.92	1.57	3.19	2.0	1.40	.20		
Do.....	1908	15.5	3.0	3.0		4.0				5.0	12.0	2.0		
Do.....	1908	.50												
Do.....	1908	5.0	Tr.											
Poker Creek.	1907								1.40	3.70	1.70	.25	1.09	
Do.....	1908		1.32		.42	.58	1.80	2.02	.69	2.45	.75	.35	.61	
Do.....	1908	.68	.09	.03	.42	1.11	1.22	2.01	2.01		4.5	6.9	4.4	12.6
Do.....	1909	8.8	2.0	.5	8.0	2.5								
Rampart.	1905						1.33	1.99	2.19	1.70	1.20	1.48	.33	
Do.....	1906	.63	.08	.17	.04	.40	.15	1.86	2.40	.59	.61	.95	.33	6.7
Do.....	1907	7.2	2.0	1.8	.5							1.02	3.5	25.2
Do.....	1907	1.17	.44	1.17	.02	.44	1.64	2.29	3.38	2.52	.65	.53	1.26	13.5
Do.....	1908	12.0	4.5	12.8	2.5							6.3		
Do.....	1908	1.08	.52	.81	.58	.82	1.38	1.13	.46	1.56	.39	.73	1.14	10.6
Do.....	1908	11.5	6.9	8.1							5.1	3.6	16.8	52.0
Do.....	1909	.09	.10	.37	.51	1.04	.85	2.01	1.41	.36	1.14	.35	1.99	10.2
Do.....	1909	1.4	1.2	6.2	5.6				1.5	14.4	3.6	20.2	54.1	
Do.....	1910	.84	.08	.36	.07	.20	.98	.71	.62	.43	.45	.26	.32	5.2
Do.....	1910	11.1	.8	4.7	1.0						6.0	3.5	5.0	32.1
Summit road house.	1907							2.71	3.27	43.33				
Tanana Crossing.	1904					.76		.78	.69	1.06	.15	.10	.90	
Do.....	1905	.24	.08	.18	.00	.14		.37	2.95		1.40	.60		
Do.....	1906	.30	.00	Tr.										

a July 16 to 31.

b Sept. 1 to 22.

Precipitation records for June to September, inclusive, at several points in the Yukon-Tanana region may be summarized as follows:

Summary of summer precipitation in Yukon-Tanana region.

Station.	Maximum.		Minimum.		Mean (inches).	Duration of records.	Precipitation for 1910 (inches).
	Inches.	Year.	Inches.	Year.			
Circle.....	7.64	1907	4.36	1908	6.38	1907-1909	
Fairbanks.....	8.37	1907	3.97	1908	5.97	1906-1910	6.22
Fort Egbert.....	9.57	1905	5.95	1909	7.09	1908, 1909, 1910	8.94
Fort Gibbon.....	10.01	1905	4.98	1908	6.59	1908-1909	5.36
Kechumstuk.....	7.88	1906	4.64	1904	6.41	1907-1910	
Rampart.....	9.83	1907	2.74	1910	5.66	1904-1908	2.74
Mean.....					6.35	1905-1910	5.83

Uniformity of precipitation throughout the Yukon-Tanana region is also noticeable, though less apparent, in the summer months. In the above table Fort Egbert has the highest average precipitation from June to September and is 12 per cent above the mean for all the stations; Rampart has the lowest average precipitation and is 11 per cent below the mean for all the stations.

The table also shows that a total precipitation as high as 10.01 inches and as low as 2.74 inches has occurred during the mining season, and it leads to the conclusion that the general scarcity of water for mining uses during 1910 throughout the Yukon-Tanana region (with the exception of the Rampart district) was not due to an unusually small amount of rainfall in the aggregate but rather to its distribution with respect to time and area. A study of the run-off from adjoining drainage basins during the four years from 1907 to 1910 indicates that a wide difference in stream flow may be expected even though geologic and topographic conditions are apparently very similar. In order to arrive at any definite conclusions regarding the areal distribution of the rainfall by a comparison of simultaneous records, it would be necessary to have a greater number of rain gages more systematically located. Such comparisons as can be made with the existing data, however, confirm the general opinion that the precipitation is distributed rather unevenly. This condition is often noticeable in the summer, when local showers visit one portion of the drainage basin and do not reach another portion.

VEGETATION.

The distribution of vegetation is shown on the map (fig. 2). Timber line is about 2,500 feet above sea level. There is a minimum of vegetation on the high ridges and their rock-strewn slopes, and a maximum in some of the larger valleys of tributaries to Tanana River. The upper zone of vegetation is characterized by more or less grass, lichens, moss, low bushes, and particularly by dwarf birch and alder. On many ridges of intermediate height the growth of dwarf birch is very dense. Most of the lower ridges and spurs near the main drainage lines are covered with a dense growth of small spruce. In the larger valleys timber is more or less abundant, especially on the sunward-facing slopes of the valleys near the main drainage lines and over portions of the valley floors. Considerable timber is more than a foot in diameter; spruce predominates, but poplar and birch are abundant in places, especially in the vicinity of the Tanana, where tamarack also is common. The most striking feature of the distribution is the contrast between the upper valleys of tributaries of the Yukon and those of the Tanana. Most of those

of the Yukon are comparatively bare or are dotted only with scattering groups of spruce, and those of the Tanana are thickly timbered from their heads. Willow and alder grow profusely along the smaller stream beds throughout the area. Grass for horse feed is abundant in many of the valleys, particularly near Yukon and Tanana rivers.

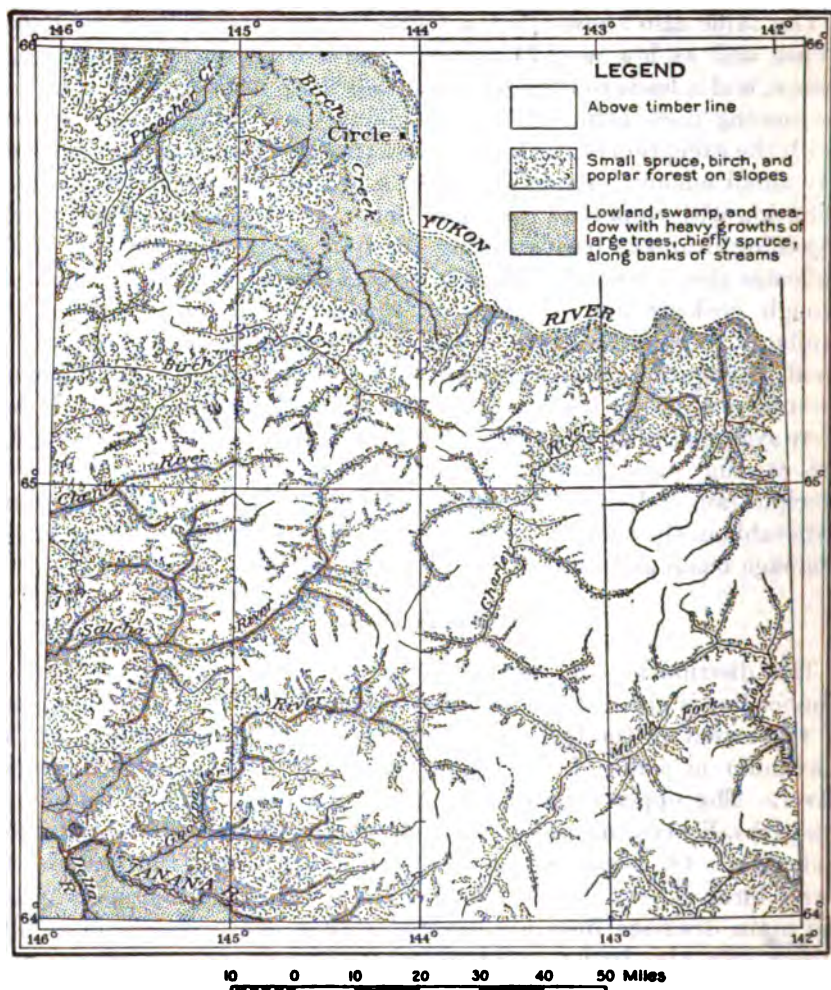


FIGURE 2.—Map showing distribution of timber in the Circle quadrangle.

Blueberries are abundant throughout a large part of the area. Currants and red raspberries grow in the vicinity of both the Yukon and the Tanana. All the hardy vegetables are grown in abundance in fine gardens in the Circle district.

POPULATION.

Most of the residents live in the northern part of the quadrangle, in the Circle district and on tributaries of the Yukon above Circle. A few prospectors are at work in the eastern, western, and southwestern portions of the area, and a few Indians spend part of the year at Kechumstuk and the mouth of the Goodpaster. The total permanent population does not exceed a few hundred.

In the Birch Creek district most of the population dwells on Mammoth, Mastodon, Miller, Eagle, and Deadwood creeks, 40 to 60 miles from Circle.

TRANSPORTATION.

The town of Circle, near the upper limit of the Yukon Flats, is the general supply point for the district and is connected with the creeks by a Government wagon road. Most of the heavy freighting is done in the winter at a cost of 3 to 6 cents a pound, but the construction of the wagon road has made it possible to obtain many kinds of supplies during the summer at only a slight advance over the winter rates, instead of, as formerly, only by pack trains at a cost of 20 to 25 cents a pound. Good road houses are located at intervals of about 12 miles along the wagon road from Circle to the creeks and others have been built upon the creeks. The trail from Circle to Fairbanks is traveled more or less every summer. The installation of a Government wireless station at Circle, connecting with other stations at Eagle, Fairbanks, and Rampart, has been of great advantage to the district.

The route for transportation from Pacific coast points to Circle is by way of either Dawson or St. Michael. The first-class passenger rate from Seattle to Circle by Dawson and the upper river in 1911 was \$85. Freight rates have a great range, depending on the freight classification; on general merchandise the rate is about \$60 a ton.

GEOLOGY OF THE YUKON-TANANA REGION.

The Yukon-Tanana region comprises many formations and has been affected by extensive metamorphism, great igneous activity, and close folding with two dominant trends—southeast-northwest and northeast-southwest.

One of the most extensive groups of rocks is made up of crystalline schists which are mostly of sedimentary origin and are regarded as pre-Ordovician. The presence of Ordovician, Silurian, Devonian, Carboniferous, Cretaceous, and Tertiary rocks has been established.

A few small areas of glacial material show that some glaciation has occurred. The alluvial materials include silt, sand, and gravel deposited either on benches or in the valleys of the present streams.

Igneous rocks are abundant. Basaltic and diabasic material, in part volcanic and in part intrusive, is plentiful, particularly in the Paleozoic sediments. Granitic and related rocks occur in many places and become increasingly abundant toward the east. They are in part metamorphosed to granitic gneisses but are mostly unmetamorphosed, and they are all, so far as observed, in intrusive relation to the rocks with which they are in contact. The period of their maximum intrusion was the Mesozoic. The evidence available points to the igneous rocks as the cause of the widespread mineralization.

The present surface is mainly the product of fluvial action and subaerial erosion acting on a surface that has changed in elevation with reference to the sea level.

GEOLOGY OF THE CIRCLE QUADRANGLE.

GENERAL FEATURES.

The mapping of the geology of the Circle quadrangle by means of a few rapid traverses has necessarily been incomplete. It has been impossible to cover the entire area, and those areas about which no information was available have been left blank. The formational boundaries indicated have not been traversed in detail and, except at a few points, must be regarded as only approximate. It is believed, however, that practically all the different formations have been observed and that the map indicates somewhat accurately their distribution.

Practically all the formations in the Fairbanks quadrangle occur in the Circle quadrangle. Some of them enter it from the western edge and extend across it into the Fortymile quadrangle. The main geologic feature in which the Circle quadrangle differs from the others is in containing large areas of igneous rocks, which occupy about one-third of the quadrangle and which, by disturbance or by contact metamorphism, have obscured the preexisting contacts between the other formations. They have intensified the metamorphism already present in the schists and have in places rendered schistose some of the Paleozoic sediments.

The following table shows the stratigraphic succession:

Stratigraphy of the Circle quadrangle.

Era.	System.	Series.	Description.
Cenozoic.	Quaternary.	Recent.	Silt, sand, and gravel.
		Pleistocene.	Morainal deposits in small isolated areas. Up to about 400 feet thick.
	Tertiary.	Unconformity	
		Eocene.	Conglomerate, sandstone, shale, and lignitic beds. Probably about 3,000 feet thick.
Mesozoic.	Cretaceous.	Unconformity	
		Upper Cretaceous (?).	Conglomerate and arkosic sandstone, occurring in disconnected areas. Probably about 1,000 feet thick.
		Lower Cretaceous.	Slate, slaty sandstone, and quartzite.
Paleozoic.	Carboniferous.		White crystalline limestone. About 200 feet thick.
	Devonian.	Middle Devonian.	Limestone and greenstone.
	Probably mostly Devonian but in part older.		Undifferentiated greenstones. Diabasic and basaltic flows, tuffs, and breccias, and serpentine. Up to 1,000 feet thick.
	Probably including Ordovician, Silurian, and Devonian.		Undifferentiated quartz-feldspar sandstone, in part schistose; quartzite, green and black shale; slate; purple and green phyllite; chert; chert conglomerate; and limestone. Probably several thousand feet thick.
			Unconformity
	Pre-Ordovician.		Birch Creek schist; quartzitic schist; quartz-mica schist; garnetiferous, staurolitic, hornblende, and carbonaceous schist; and crystalline limestone. Probably several thousand feet thick.

SEDIMENTARY ROCKS.

PRE-ORDOVICIAN ROCKS.

BIRCH CREEK SCHIST.

Lithologic character.—One of the most widespread formations in the quadrangle is the Birch Creek schist, which includes quartzite schist, quartz-mica schist, garnetiferous, and staurolitic schist, carbonaceous schist, hornblende schist, and crystalline limestone. Its most common type is a rather blocky quartzite schist in beds which have a maximum thickness of several feet and which alternate with thin-bedded micaceous schist that is locally garnetiferous. (See Pl. VIII, A.) Mica, both muscovite and biotite, is the most widely distributed metamorphic mineral and by its abundance distinguishes

the Birch Creek schist from the Paleozoic formations, in which mica has been developed but rarely, except in close contact with igneous rocks. Garnets are generally found throughout the area where the schists form the bedrock, and near some of the granitic contacts they are especially abundant. In some places, notably about the heads of Coal and Woodchopper creeks, the garnets are accompanied by staurolite, which is abundant in crystals half an inch or less in length. The crystalline limestones interbedded with the schists are also schistose in part, containing considerable mica and in some places much garnet. The distribution of metamorphism is not uniform. In some localities the rocks are comparatively massive quartzites, with but a small amount of mica and but slight schistosity, and there are all gradations between such rocks and quartz-mica schists that show little evidence of their origin. At many localities in the vicinity of granitic intrusives the schists are feldspathic and, close to the contact, are essentially augen gneisses.

The formation apparently becomes increasingly gneissoid with depth, and the observed facts indicate that at the base it is closely welded to ancient granitic intrusives that have been metamorphosed to gneisses by the same process that metamorphosed the quartzites and interbedded slates to schists. The gneisses are in part more or less even and medium grained and in part coarse augen gneisses with feldspars 2 inches or more in diameter. (See Pl. VIII, *B*.) Most of them occur in bands from a few inches to several hundred feet in thickness, lying parallel to the structure of the schists.

The contact-metamorphic action on the schists has apparently increased the schistosity, developed garnet, staurolite, feldspar, additional mica, especially biotite, and in some places andalusite. The prevailing contact metamorphism in the Paleozoic rocks, on the other hand, consisted in the production of hornfels with more or less andalusite or cordierite.

The original succession of the schists is obscured by the complex structure resulting from several periods of folding. The succession from bottom to top is apparently fine-grained quartzitic and quartz-mica schists; garnetiferous quartz-mica and hornblende schist with thin interbedded quartzitic beds; quartz-mica schist, very micaceous; and carbonaceous schists.

Limestone occurs sparingly at different portions of the section and apparently becomes more abundant toward the top. It appears not to be persistent, but to occur in more or less lenticular form. The fact that it is particularly abundant in the Fortymile quadrangle caused Spurr¹ to name it the Fortymile series. In the other quadrangles, however, it seems to be but a subordinate nonpersistent phase of the formation.

¹ Spurr, J. E., *Geology of the Yukon gold district, Alaska: Eighteenth Ann. Rept. U. S. Geol. Survey*, pt. 3, 1898, pp. 145-155.



A. BIRCH CREEK SCHIST.



B. AUGEN GNEISS INTRUSIVE INTO BIRCH CREEK SCHIST.

The upper limit of the formation is not everywhere distinctly separated from the succeeding unconformable Paleozoic rocks. In most places, however, the coarser detrital material of the lowest Paleozoic and its prevailing lesser degree of metamorphism serve to differentiate it. In different areas, too, different members of the Paleozoic rest upon the schist, and in some localities there is a distinct, lithologic change from the schists to the overlying rocks.

Structure.—The schists have a very complex structure. They have been closely folded, and most of the folds have been closely appressed and overfolded to a nearly horizontal position. The planes of schistosity thus correspond to a certain extent with the planes of the axes of the minor folds and the structure simulates the horizontal.

Distribution.—The fact that most of the occurrences of gold in the Yukon-Tanana region, including those of the Fairbanks and Circle districts, are within areas of Birch Creek schist renders the distribution of these rocks a matter of economic importance. The main body of schist that includes the Circle district is continuous to the southwest with that of the Fairbanks district, and is flanked on both the northwest and the southeast by belts of Paleozoic rocks. It extends eastward, round the heads of Woodchopper and Coal creeks, flanking the large mass of granite on Charley River, and terminates in the Seventymile region. Another belt extends northwest and southeast just north of the Tanana. A part of it forms apparently but a narrow strip of schist flanking the large area of granite that lies southeast of the Circle quadrangle, and another part extends more or less uninterruptedly to the area in the Fortymile region between Middle Fork of Fortymile River and Mosquito Fork.

Age.—The age of the Birch Creek schist is not definitely known. The oldest fossils that have been found in the Paleozoic rocks of the Yukon-Tanana region are Ordovician. These, however, occur at a considerable distance above the base of the Paleozoic, and in the absence of more definite information and in view of the possibility that some of the schists may be of Cambrian age it has seemed desirable to call them pre-Ordovician.

PALEOZOIC ROCKS.

CORRELATION WITH ROCKS OF THE FAIRBANKS QUADRANGLE.

Paleozoic rocks occur extensively in the western portion of the Yukon-Tanana region and in the Yukon Valley between the mouth of the Tanana and the international boundary. The Paleozoic rocks in the Circle quadrangle are extensions of those in the Fairbanks quadrangle. The same lithologic types are present and detailed work would probably reveal the same formations. From reconnaissance work, however, the fact seems fairly well-established that except in the area along the Yukon, the Paleozoic section in the Circle

quadrangle is thinner than that in the Fairbanks quadrangle and that the strata composing it are less persistent, less individualized, and represent the peripheral rather than the main portions of the formations. For example, the conspicuous limestones so characteristic of the Fairbanks quadrangle are represented in the Circle quadrangle by more or less lenticular beds not much exceeding 100 feet in thickness. The same is true of the greenstones, which form a considerable proportion of the Paleozoic rocks and in some localities attain topographic prominence but which, in general, are less abundant and less conspicuous than in the western portion of the Yukon-Tanana region. Therefore, although the available facts indicate the stratigraphic equivalence of the Paleozoic of the Circle quadrangle with that of areas farther west, they further indicate that it is less differentiated into formations.

LITHOLOGIC CHARACTER.

The principal Paleozoic rocks of the Circle quadrangle are coarse quartz-feldspar sandstones, metamorphosed and more or less schistose, quartzite, shale, slate, phyllite, chert, chert conglomerate, greenstone, and limestone. The dominant lithologic types have been derived from sandy and argillaceous sediments.

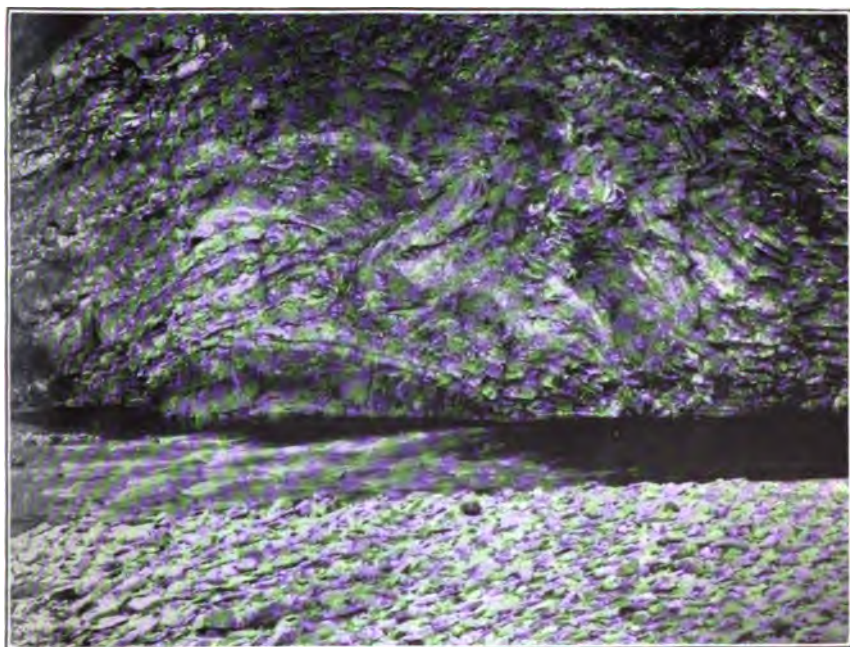
The quartz-feldspar sandstone is like that which forms so large a part of the Tatalina group in the Fairbanks quadrangle and is regarded as being of the same age. The most common type is composed of about equal proportions of rather coarse quartz and feldspar grains in a finely granular matrix of the same materials admixed with considerable argillaceous matter. In the coarsest varieties the grains are half an inch or more in diameter. The rocks are in general considerably metamorphosed. The quartz and feldspar grains are reduced more or less to augen, and considerable sericite mica has been developed. These rocks are interbedded in some places with fine-grained quartzitic beds, purple, drab, or green shaly slates, and limestones. In some areas the fine-grained beds have become typical phyllites. Where these rocks have become schistose some of them resemble the Birch Creek schist, but in general they may be distinguished from the Birch Creek by their composition.

The most common colors of the shale are gray, green, and black. Black carbonaceous shales are abundant and in some areas are interbedded with cherts. Green shales also are widely distributed and occur in very many places in close association with the greenstones.

The greenstones are mostly altered diabasic and basaltic flows and tuffs, but they include also some reddish-weathering serpentine derived from more basic rocks. The serpentine is described in more detail in connection with the igneous rocks (p. 42). The greenstones are characteristic of the Paleozoic section in the Yukon-Tanana region, and wherever they appear they accentuate the relief, forming



A. CONTORTED FELDSPATHIC QUARTZITE, SALCHA RIVER.



B. CONTORTED CALCAREOUS SHALES, INDEPENDENCE CREEK.



steep, pointed, jagged ridges, or being cut by streams into steep-walled narrow canyons. Their distribution, so far as known, is shown on the map (Pl. II), but the fact must be emphasized that only some of them are shown and that they may be found in any of the Paleozoic areas.

Owing to the fact that the Paleozoic limestones occur chiefly as interbedded members of little thickness, it has not been practicable to show them on the map. They are prevailingly gray or bluish, are more or less massive, and have been so closely folded that in most places their primary structures have been practically obliterated. At one locality on the Yukon west of Coal Creek a white limestone of Carboniferous age outcrops.

STRUCTURE.

The close folding (Pl. IX) has rendered the succession difficult to interpret. The lower part of the section seems to be composed mainly of coarse and fine sediments, largely feldspathic, succeeded by shales, chert, and chert conglomerates. The top seems to be mainly greenstone and limestone, the limestone being thicker and more massive than that in the lower portion. At some localities greenstones were observed to underlie the limestone and at others to overlie it.

AGE.

Apart from the Devonian localities and the locality of Carboniferous limestone, the relation of which to the rocks above described is not known, the only locality where paleontologic evidence of the age of the Paleozoic rocks has been obtained is near the eastern edge of the quadrangle, west of North Fork of the Fortymile, where a few poorly preserved fossil corals were found. These fossils, however, are too indefinite to be of value in correlation.

In the lack of definite evidence in the rest of the quadrangle it seems very probable, on lithologic grounds alone, that the same periods are represented as in the western part of the Yukon-Tanana region and that the Ordovician, Silurian, and Devonian and possibly other areas of Carboniferous are all present.

DEVONIAN SYSTEM.

The Paleozoic rocks along the Yukon within the Circle quadrangle have been studied by Brooks and Kindle,¹ who found them to be mainly Devonian. The following fossils obtained by them were referred by Kindle to the Middle Devonian:

Fossils were found at a number of localities in the limestones. At some exposures opposite the mouth of Woodchopper Creek and about 1 mile farther up the Yukon the fauna following occurs in limestones interbedded with tuffs.

¹ Brooks, A. H., and Kindle, E. M., Bull. Geol. Soc. America, vol. 19, 1908, pp. 277-291.

Cyathophyllum sp.
 Crinoid stems.
 Stropheodonta cf. calvini Miller.
 Camarotoechia, small sp.
 Atrypa reticularis Linn.
 Atrypa cf. flabellata Goldf.
 Schizophoria striatula (Schlotheim).
 Ambocoelia cf. umbonata (Conrad).

Anoplothea? concava (Hall).
 Dalmanella sp.
 Spirifer sp.
 Rensselaeria? sp.
 Cypricardinia sp.
 Conocardium sp.
 Actinopteria near perstrialis Hall.
 Pleurotomaria sp.
 Sigaretus? n. sp.

This is the same fauna and horizon as that occurring at the mouth of Salmontrout River on the Porcupine. *Atrypa cf. flabellata* is one of the most abundant species in both faunas. The very peculiar gastropod here referred doubtfully to *Sigaretus* and *Stropheodonta cf. calvini* are also common to both.

About 2 miles below Woodchopper Creek the igneous beds, which are there the predominant rocks, are interrupted by a cliff of bluish-gray Devonian limestone rising 200 feet above the river. Fossils are very scarce here. The following species were obtained:

Crinoid stems.
 Atrypa reticularis.
 Camarotoechia sp.

Stropheodonta sp.
 Conocardium sp.

The section in this area has been summarized by Brooks and Kindle as follows:

If one were to venture on a subdivision of this great series on the facts in hand, it would be to recognize three general groups. The lowest group would comprise the heavy cherty bluish-white limestones and associated argillites, quartzites, and thin-bedded limestones occurring below Woodchopper Creek, which may be Silurian and are characterized by a relatively small amount of igneous material. The cherts, quartzites, and limestones of the Washington Creek area are provisionally included with the formation. The lowest member of the Devonian or upper Silurian described by Prindle in the Rampart region, and probably also the rocks of the Stewart River, assigned to the Devonian by Keele, can be provisionally correlated with this general horizon.

A second group would include limestones and the associated igneous rocks, argillites, and cherts. The igneous rocks of this group would appear to be identical with Spurr's Rampart series; but it must be remembered that it is only for the limestone member of this group that the age has been determined and that the igneous rocks may be somewhat younger. In its typical occurrence this igneous group is undoubtedly the best defined of the stratigraphic subdivisions here proposed for the Devonian. As a cartographic unit, however, it is not serviceable, because including, as it does, some intrusives, these are likely to be found as dikes crosscutting various older formations. Moreover, the equivalent of this igneous complex in adjacent areas may be found among the purely sedimentary rocks. The stratigraphic relations of Middle Devonian horizon to the older rocks here assigned to the Devonian is not known, but may very likely be one of unconformity.

The third group includes the argillites and subordinate sandstones and siliceous slates, which occur immediately underneath and conformable to Mississippian terranes. These rocks are but sparingly fossiliferous, and may be found to be in part of synchronous age with the igneous complex of the second group. If the argillite group is distinct from the igneous group, there may be an unconformity between the two, and the apparent absence of the latter in many localities may be due to erosion, which removed the igneous rocks before the sediments were laid down.

Little can be said of the thickness of the Devonian in this Province. The heavy limestones and associated rocks of the lowest group may measure several thousand feet.

It is probably safe to estimate that the exposures along the upper Yukon of Middle Devonian limestones and associated greenstones indicate a thickness of from 5,000 to 8,000 feet, much the larger part of which is made up of igneous rocks. The upper argillites and associated sandstones are roughly estimated to have a thickness of about 1,000 feet.

CARBONIFEROUS SYSTEM.

The Carboniferous limestone on the Yukon near Coal Creek has been described by Brooks and Kindle¹ as follows:

The upper Carboniferous limestone is typically exposed in some large open folds, accompanied by more or less faulting, along the north side of the Yukon for some 3 or 4 miles above Nation River. The same horizon was identified about 30 miles below, on the south side of the river and just west of the mouth of Coal Creek. Here it is exposed in a small area closely associated with some pyroclastic material similar in every way to that occurring with the Devonian rock. Were not the paleontologic evidence in regard to this occurrence conclusive, this limestone would have been placed with the Devonian. The occurrence, however, goes to prove that there was some igneous activity during late Carboniferous time. It also suggests the possibility that some of the igneous rocks which have been mapped as Devonian may eventually prove to belong to the Carboniferous.

The fauna characterizing this highest Carboniferous limestone is shown in the following list of fossils determined by Dr. Girty:

Lot 14: Fossils from west bank of Yukon, 1½ miles above Nation River.

Zaphrentis sp.	Aulosteges sp.
Stenopora sp.	Marginifera aff. splendens Norwood and Pratten.
Streptorhynchus aff. S. pelargonatus Schlot.	Spirifer aff. marcoui Waagen.
Chonetes aff. morahensis Waagen.	Squamularia aff. perplexa McChesney.
Productus aff. horridus Sowerby.	Spiriferella arctica Houghton.
Productus aff. saagardi Toula.	Cleiothyrodina n. sp.
Productus aff. P. porrectus Kut.?	Rhynchopora aff. nikitini Tschern.
Productus aff. mammatus Keys.	Schizodus sp.
Productus aff. iringiæ Kut.	Aviculipecten sp.
Productus aff. koninckianus Vern.	Omphalotrochus sp.
Productus sp.	

Lot 15: Fossils from limestone 1½ miles southeast of mouth of Nation River.

Streptorhynchus aff. S. pelargonatus Schlotheim.	Aulosteges sp.
Productus aff. saagardi Toula.	Marginifera ? aff. splendens Norwood and Pratten.
Productus aff. koninckianus Vern.	Spiriferella arctica Houghton.

Lot 22: Fossils from south bank of the Yukon below Glenn Creek.

Polypora sp.	Spirifer aff. cameratus Tscherny. non Morton.
Rhombopora sp.	Spiriferella aff. artiensis Stuckenberg.
Streptorhynchus aff. pelargonatus Schlotheim.	Spiriferella arctica Houghton.
Productus aff. transversalis Tscherny.	Squamularia aff. perplexa McChesney.
Productus aff. saagardi Toula.	Camarophoria margaritovi Tschern.
Productus aff. koninckianus Vern.	Aviculipecten 2 sp.
Productus aff. porrectus Kut.?	Fish tooth.
Marginifera? aff. splendens Norwood and Pratten.	

¹ Brooks, A. H., and Kindle, E. M., op. cit., pp. 295-297.

"This fauna is unlike anything known in central and eastern North America, and appears to be rather closely allied to that of the Gechelstufe of the Ural Mountains. Probably the fauna of the Hueco, Weber, and Aubrey formations of western United States will be found more or less closely related. In Alaska it has been collected also in Pybus Bay and on Kuiu Island."

Lots 14 and 15 represent the limestone in its typical development, while the limestone which furnished lot 22 is associated with beds of igneous origin. The limestone, which is of upper Carboniferous age, terminates the Paleozoic section in the upper Yukon region. The succeeding strata in the section were not observed in direct superposition, but a series of argillites, with one or more limestone beds, is believed to hold this position. A collection of fossils was made in this series half a mile above the mouth of Nation River, from a limestone about 15 feet in thickness. A species of *Halobia* is the most abundant fossil in this collection. Dr. T. W. Stanton refers the fauna provisionally to the Triassic. If this provisional determination is correct, the upper Carboniferous limestone of the Yukon section is limited above by rocks of Triassic age.

The Carboniferous rocks above described show practically no metamorphism, and are in strong contrast in this respect to all the older rocks of the Yukon except the uppermost member of the Devonian. It is also noteworthy that, with the single exception of the pyroclastics found with the upper Carboniferous limestone at Glenn Creek, there is no evidence of igneous activity during the deposition of the Carboniferous sediments of the upper Yukon.

Near the mouth of Michigan Creek, on the south side of the Yukon, nearly opposite the mouth of Nation River and east of the Circle quadrangle, Mr. Mertie obtained in 1911 additional paleontologic material, on which Mr. Girty made the following report:

The species which these collections contain are as follows:

A(JBM)40. Michigan Creek, about 6 miles from mouth (south of Yukon).

Stenopora? sp.	Productus aff. wallacianus Derby.
Streptorhynchus? sp.	Dielasma n. sp. aff. elongatum Schlot- heim.
Chonetes aff. morahensis Waagen.	Rhynchopora aff. nikitini Tchernyschew.
Productus aff. horridus Sowerby.	Squamularia aff. perplexa McChesney.
Productus aff. aagardi Toula.	

A(JBM)41. Michigan Creek, about 3 miles from mouth.

Derbya? sp.	Productus aff. wallacianus Derby.
Productus aff. horridus Sowerby.	Rhynchopora aff. nikitini Tchernyschew.
Productus aff. mammatus Keyserling.	Spirifer aff. marcoui Waagen.
Productus aff. aagardi Toula.	Spiriferella artica Houghton.

The fauna of the two lots is essentially the same and clearly corresponds to that obtained by Brooks and Kindle on the Yukon near the mouth of Nation River. [See p. 29.] From its resemblance to the fauna of the Russian Gechelstufe, as described by Tchernyschew, I take the geologic age to be "upper" Carboniferous rather than Permian. The facies is, of course, widely different from either the Pennsylvanian or the Permian of the Mississippi Valley and Appalachian regions.

MESOZOIC ROCKS.

LOWER CRETACEOUS SERIES.

The only rocks of known Mesozoic age in the Circle quadrangle are the Lower Cretaceous rocks on the south side of the Yukon. These rocks were studied in 1906 by Brooks and Kindle,¹ from whose report the following statement is quoted:

The Lower Cretaceous of the upper Yukon comprises a series of closely folded rocks characterized by a large amount of silica. They included primarily siliceous slates, slaty sandstones, and quartzites, with which are associated some argillites and pyroclastics. One heavy bed (50-75 feet thick) of massive tufaceous conglomerate was observed within the Mesozoic area about 5 miles below Washington Creek, but may be an infolded older or younger terrane. The pebbles of this conglomerate, which are chiefly limestone, are well rounded, and some are 2 feet in diameter. The dominating rock type of the Lower Cretaceous is a siliceous slate or quartzite, sometimes interbedded with a clay slate. These rocks are usually pyritiferous and iron-stained when weathered. Three miles below Washington Creek there is a series of beautifully banded slates and quartzites. Here the brittle quartzite is broken by a series of fractures at right angles to bedding, while the same movement has in large measure been taken up in the cleavage of the slate. A quartz filling, sometimes carrying pyrite, is not uncommon along these fractures. In at least one instance it appears to be established that quartz veins cutting these Cretaceous rocks are auriferous. This conclusion is not without importance in its bearing on the age of the mineralization which produced the auriferous deposits of the Yukon.

These rocks in a general way strike easterly and northeasterly, but there are many local variations. They are usually closely folded, and no determination of thickness, which probably does not exceed a few thousand feet, could be made. On Washington Creek they appear to rest unconformably on the Devonian and in turn are unconformably overlaid by the Tertiary beds. Near Coal Creek the Aucella-bearing beds seem to underlie the upper Carboniferous limestone, which has apparently been thrust over them.

Fossils were collected from three localities in this formation, which were reported upon by Dr. T. W. Stanton as follows:

"Lot 18. South bank of Yukon River, 400 yards below Glenn Creek. This lot includes many fragmentary specimens and impressions of an *Inoceramus*, with a few imperfect specimens of *Pecten*, *Pinna*, two small specimens doubtfully referred to *Aucella*, and a few other small undetermined bivalve shells, together with very imperfect fragments of an ammonite possibly belonging to the genus *Perisphinctes*, or some other genus with a similar sculpture. The horizon of this lot is evidently either Jurassic or Lower Cretaceous, but the nature of the material does not permit a discrimination between these two periods. I judge that these fossils came from the same series as the *Aucella* mentioned below.

"Lot 19. North bank of Yukon River, 6 miles above Charlie village. This collection contains numerous specimens of *Aucella* cf. *crassicollis* Keyserling. This is provisionally referred to the Lower Cretaceous, although the possibility that it may be Jurassic should not be forgotten.

"Lot 21. South bank of the Yukon River, 1½ miles below Sams Creek. This small lot contains two imperfect specimens of *Aucella* and a few small fragmentary imprints of *Inoceramus*. The horizon is probably the same as that of lot 19.

¹ Brooks, A. H., and Kindle, E. M., op. cit., pp. 306-307.

"The reference of these three lots of fossils provisionally to the Lower Cretaceous is made with the same reservation that has so often been expressed when similar collections containing Aucella and only a few associated forms have been submitted from this and other areas in Alaska—that is, while the Aucella itself is indicative of probable Cretaceous age, closely related species are known in the Jurassic, and it may be that all of the Aucella beds of Alaska are Jurassic."

UPPER CRETACEOUS (1) SERIES.

A few areas of conglomerate and arkosic sandstones were found in 1911 near the main divide between the drainage areas of Charley River, Goodpaster River, and Salcha River. The areas, so far as observed, are comparatively small and occur in different valleys at elevations between 3,000 and 4,000 feet above sea level.

The material varies greatly in coarseness. The coarsest varieties contain a large proportion of granitic boulders, some of them nearly 6 feet in diameter, locally embedded in fine sandy beds. The next commonest type is made up of beds of cobbles not exceeding 6 inches in diameter alternating with shaly beds that in places carry poorly preserved plant remains. A common type is a medium-grained even-bedded arkosic sandstone that splits readily along the planes of sedimentation into slabs, many of whose surfaces are more or less colored with carbonaceous matter derived from plants. These rocks are composed of about equal quantities of quartz and feldspar grains, with some mica. They are gray in color, well consolidated, and gritty. The material has apparently traveled but a short distance from the granitic rocks from which it has been derived and it is apparently coarsest where closest to its source. The rocks where observed are but slightly tilted and their thickness probably does not exceed 1,000 feet.

No similar rocks have been observed in other areas of the Yukon-Tanana region. Conglomerates and gritty carbonaceous sandstones, found by the writer in the Rampart region,¹ contain Upper Cretaceous fossils and have at their base a conglomerate that in degree of coarseness resembles the medium coarse type of those under discussion.

The Upper Cretaceous rocks of the Rampart region have been intruded by granitic bodies, and the fact that the similar rocks of the Charley River country are composed largely of granitic material shows that they were deposited subsequent to some granitic intrusions, and in the lack of definite evidence they are referred provisionally to the Upper Cretaceous.

¹ Prindle, L. M., The Fairbanks and Rampart quadrangles, Yukon-Tanana region, Alaska: Bull. U. S. Geol. Survey No. 337, 1908, pp. 23-24.

CENOZOIC ROCKS.

TERTIARY SYSTEM.

Distribution.—Rocks of Tertiary age occupy an area of considerable extent in the vicinity of Yukon River. They enter the area from the Fortymile quadrangle and extend in a probably continuous belt, with a maximum width of about 10 miles, to Woodchopper Creek and beyond toward Circle. It is probable that Tertiary rocks occur also in the upper Charley River valley, as lignite has been reported from that locality, but if they do they probably form an isolated occurrence in the large mass of granitic intrusive rock.

Lithologic character.—The Tertiary rocks include clay, sandstone, shale, lignite, and conglomerate of very different degrees of consolidation, some of the sandstone and conglomerate being but loosely cemented, some of the clays having become shales, and some of the conglomerates having been thoroughly cemented. Clay and sandstone and interbedded lignite apparently constitute the basal formation.

The most conspicuous portion of the Tertiary is the conglomerate which forms the upper part of the section. This rock makes rugged topography. Most of the valleys cut into it by the main streams are narrow canyons with somewhat wider upper portions bordered by spurs that are in general precipitous or comparatively steep sided.

The conglomerate is composed mostly of fragments of black, gray, green, and red chert, quartzite, and vein quartz but includes numerous fragments of Birch Creek schist and a few pebbles of granite, found mostly near the southern edge of the formation. The pebbles of the conglomerate are well worn and commonly range from about 1 to 3 inches in size, though the maximum is about 5 inches. Boulders 2 feet or more in diameter occur sparingly. The conglomerate merges into a coarse whitish sandstone resembling mortar. Ferruginous material is a common cement not only of the conglomerate but also of the brownish Tertiary sandstones. On the ridges the conglomerate is for the most part weathered to heaps of gravel resembling ordinary stream gravels.

The thickness of the Tertiary is perhaps 3,000 feet, about equally divided between the argillaceous, sandy, and lignitic lower portion and the conglomeratic upper portion. The rocks have been in places closely folded, and at many localities along Seventymile River are nearly vertical.

Deposition.—The origin of the Tertiary deposits has been a subject of much discussion among the miners. The conglomerates are regarded by them ordinarily as old channel gravels of river origin.

The underlying fine materials—clays, sandstones, and lignites—contain the same fossils as the conglomerates. The lower deposits are the product of conditions under which predominantly fine material was deposited. The conglomerates, on the other hand, are the product of conditions under which predominantly coarse but well-worn material was deposited. It would appear that the finer material was deposited in a lowland area where the streams were sluggish, where lakes could form, and where in swampy areas material for lignite beds could accumulate. The conglomerate, on the other hand, was probably deposited where more active erosion was in progress and is probably in larger part the product of fluvial action. It must be borne in mind, however, that the Tertiary deposits could not have been laid down by any river system that was not much older than the present valleys; that they are in no wise related to the White Channel gravel of the Klondike or to any other high gravels that are referable to the present drainage systems; that since their deposition they have undergone not only consolidation but folding, until many of their beds are vertical; and that their history, therefore, is entirely discontinuous with that of the present drainage systems.

Age.—By means of the fossil plants, which are in places very common, the age of the rocks has been determined to be Eocene (Kenai). A few miles east of the quadrangle, in the Seventymile Valley, fossil leaves occur in ferruginous nodules in the lower shales, in sandstones interbedded with the shales, and in shales interbedded with the conglomerates.¹

QUATERNARY SYSTEM.

Glaciation and glacial deposits.—Evidence was obtained during 1911 that glaciation formerly occurred to a minor extent in some of the highest portions of the quadrangle and that the normal drainage had been somewhat modified thereby. Only the heads of valleys and the valleys of minor tributaries were affected. Cirques, U-shaped valleys, and morainal deposits were observed. Some of the cirques are firmly developed (Pl. X, A) and form hanging valleys, the present drainage having cut only narrow V-shaped gashes in their mouths. Some of the U-shaped valleys (Pl. X, B) are also clearly shown. They are flat floored and are practically bare of deposits except at their very heads. The morainal material begins near their opening on the larger valleys and extends into these valleys more or less irregularly. (See Pl. XI, A and B.)

The distribution of the glacial deposits as far as known is shown on the map (Pl. II), but more detailed investigations would undoubtedly reveal their presence in many other localities. Their occurrence is governed largely by the intrusive rocks and their immediate con-

¹ Prindle, L. M., *The Fortymile quadrangle*: Bull. U. S. Geol. Survey No. 375, 1909, p. 23.



A. CIRQUE, HEAD OF SALCHA RIVER.



B. U-SHAPED VALLEY, TRIBUTARY OF CHARLEY RIVER.



A. MORaine PARTLY DAMMING VALLEY.



B. TERMINAL SLOPE OF MORaine FROM SMALL VALLEY.

tacts, because these are the only areas that attained sufficient altitude to furnish conditions favorable for the development of glaciers. They are most common on the headwaters of Charley River.

One of the most conspicuous glacial deposits in the quadrangle is a moraine about $1\frac{1}{2}$ miles long and half a mile wide occurring in a small valley trending N. 15° W. from a peak 6,284 feet high. (See Pl. XII.) The valley is U-shaped and has a floor about 500 feet wide. The morainal material begins near the mouth, where it has a thickness of about 400 feet. At the lower end of the moraine, $1\frac{1}{2}$ miles distant in the main valley of Charley River, the thickness is about 100 feet. The material is arranged in three more or less concentric ridges, the outermost being the largest. The innermost ridge is confined to the immediate vicinity of the mouth of the valley.

These deposits constitute an unconformable feature among the normal alluvial deposits. Nothing very definite is known regarding their age. They have been somewhat reworked by the present streams but are younger than the main valleys. It is probable that they were more or less contemporaneous with the benches of intermediate height (p. 15). The conditions favoring their development may have prevailed from late Pleistocene to comparatively recent time in only a small area where the altitude was favorable, but later these conditions shifted northward and at present prevail in the mountains north of the Yukon, as shown by small existing glaciers.

Alluvial deposits.—The alluvial deposits include gravel, sand, and silt that have been deposited either on benches at various levels or on the flood plains of the present streams. The high bench gravels so common in the Fortymile and Rampart quadrangles, where they occur at various levels not exceeding 500 feet above the present streams, have been observed at but a few localities in the Circle quadrangle. High benches are well developed in places, notably in the valley of the Seventymile (Pl. V, B, p. 14), where a bench 500 feet above the stream seems so closely related to the present valley of the Seventymile that it is probably a part of the old valley in which the river has cut its present canyon-like valley. No gravels, however, were observed on this bench, though they occur on the lower rock-cut benches, especially on a sharply defined bench about 20 feet above the present stream.

The gravels have been derived from the bedrock of the valleys in which they occur, and with the exception of the small aggregations of morainal material above described are of fluvial origin. They are described in more detail in connection with the gold placers.

The silts are characteristic deposits along Yukon and Tanana rivers and occur in places in the lower valleys of their tributaries. They have been deposited at various levels at and above that of the present streams.

IGNEOUS ROCKS.

By J. B. MERTIE, JR.

GENERAL FEATURES.

Roughly, probably one-third of the Circle quadrangle is occupied by eruptive rocks and the greater part of the remainder by crystalline schists and gneisses. Many of the gneisses and some of the schists are closely connected in origin with the eruptive rocks, and igneous activity has therefore played a very important part in the history of the region.

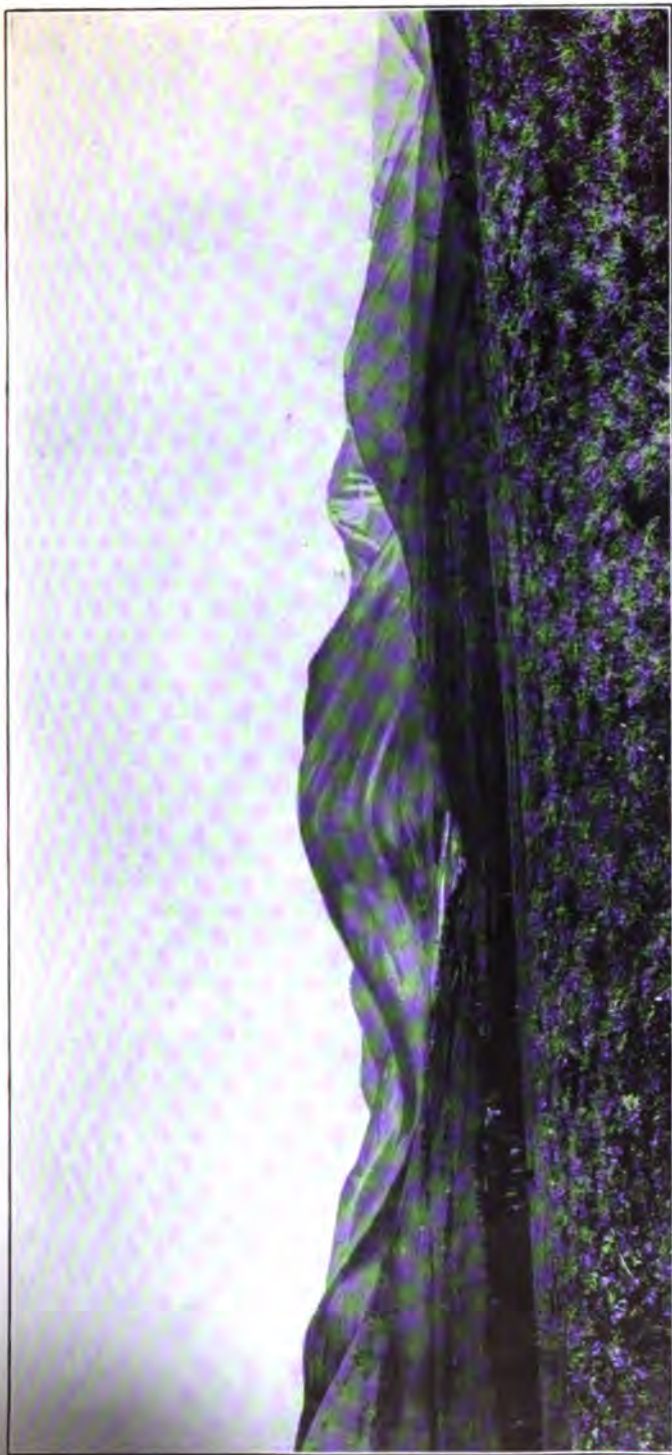
For purposes of discussion the igneous rocks may be divided into plutonic rocks, such as granites and diorites, and volcanic rocks, such as rhyolites and basalts, although these classes, strictly speaking, are not mutually exclusive. In the class of plutonic rocks are included all the intrusive rocks that crystallized at considerable depths beneath the surface or under conditions similar to those that exist at considerable depths. All such rocks appear wholly crystalline to the naked eye. In the class of volcanic rocks are included all the rocks that crystallized at the surface or under conditions simulating those at the surface, as, for instance, in many dikes and volcanic plugs. The volcanic rocks thus include all the extrusive and some of the intrusive rocks. Such rocks are either microcrystalline or partly glassy.

PLUTONIC ROCKS.

DISTRIBUTION AND AGE.

The plutonic rocks, both geographically and geologically, are the most important igneous rocks of the Circle quadrangle. They occur as dikes and irregular intrusive bodies and the areas covered by them vary greatly in size. In the east-central part of the Circle quadrangle there is an area of granitodioritic rock approximately 70 miles long and 50 miles wide, which connects on the east with the intrusive mass that forms Glacier Mountain in the Fortymile quadrangle. As prospectors have reported coal from the center of this mass it is probable that it contains a small basin of younger unaltered sedimentary rocks. Nevertheless, its extent gives some idea of the large scale on which the intrusive action has occurred.

It is probable that all the plutonic rocks were not intruded simultaneously, for in several localities acidic granites cut basic granites and diorites. A conglomerate which is regarded as Cretaceous in age has been found to contain boulders of basic granite and diorite, and for this reason it is likely that some of the more basic granodioritic rocks were intruded previous to a part at least of the Cretaceous. The intrusions probably took place at several periods during the Mesozoic



MORaine NEARLY FILLING MAIN VALLEY FROM SMALL VALLEY HEADING IN PEAK IN BACKGROUND.

era. In the Rampart region, farther west, Upper Cretaceous rocks have been intruded.

The regional strike of the crystalline schists is northwest and southeast, and many of the intrusive bodies lie in conformity with this major structural direction. For instance, the large intrusive mass 50 miles wide, previously mentioned, narrows toward the southeast to 12 miles and toward the northwest, along the ridge at the heads of Coal, Woodchopper, Webber, and Thanksgiving creeks, to but 2 or 3 miles.

METAMORPHISM.

In general, the plutonic rocks have not suffered extensive regional metamorphism. The Eocene conglomerate, however, which is younger than the plutonic rocks of the region, has been closely folded, the strata at some localities being vertical. This Tertiary movement should have had some effect on the plutonic rocks, and possibly the gneisses that occur on the periphery of the large granite and diorite masses were largely due to it. The later metamorphism was probably insufficient to leave traces in the interior of the large intrusive bodies, but was able to affect them along their contacts, where the movement was locally intensified. On the other hand, some of the gneissoid structure seems to be primary.

UNMETAMORPHOSED PLUTONIC ROCKS.

GRANITIC ROCKS.

Granitic rocks are the most common igneous rocks in the Circle quadrangle, occurring in many varieties depending on the character and amount of the feric minerals. The common feric minerals observed were muscovite, biotite, hornblende, tourmaline, and epidote, and the rocks have been so named as to indicate the dominant one of these minerals present.

Muscovite granite and alaskite.—In the hand specimens the muscovite granite and alaskite range from fine to coarse grained varieties and are invariably light in color. In composition they range from the muscovite granite proper, in which muscovite is abundant, to alaskite, which consists essentially of quartz and feldspar, with muscovite or biotite developed only in subordinate amount. As accessory minerals garnet, apatite, zircon, and oxides of iron commonly occur. The feldspars are chiefly orthoclase and microcline, with subordinate amounts of plagioclase, ranging in composition from albite to basic oligoclase. In some specimens the orthoclase and microcline are graphically intergrown with the quartz, giving rise to a graphic granite.

The muscovite granite and alaskite occur in small amount compared with the biotite and hornblende granite, and it is evident that

they are relatively unimportant. Good-sized bodies of muscovite granite are present in a few localities, as for instance along the divide at the head of Coal Creek, but for the most part it occurs as dikes cutting the other granitic rocks and the metamorphosed sedimentary rocks.

Muscovite-biotite granite.—Muscovite-biotite granites or granites which carry muscovite and biotite in approximately equal amounts represent the true granite type, or granite as the term is used in the narrow sense. They do not differ greatly in appearance or in general character from the muscovite granite and alaskite group. In the field some of them appear slightly darker by reason of their content of biotite, but in others the biotite has been leached and can be told from muscovite only by the aid of the microscope. In the specimens examined the potash feldspar is chiefly orthoclase and the plagioclase is oligoclase. The accessory constituents are apatite, zircon, and garnet. In places epidote is developed as a secondary product.

In mode of occurrence and relative importance the true granites do not differ materially from the muscovite granite and alaskite. They occur both in dikes and in larger bodies and are probably more closely related in age to the acidic granites than to the basic types. In general they appear to grade into muscovite granite and alaskite on one hand and into biotite granite on the other.

Biotite granite.—Biotite granite seems to be the dominant rock in the Circle quadrangle. It is composed largely of quartz, feldspar, and biotite, all three of which are as a rule visible in hand specimens. Orthoclase and microcline are both developed, although the former is the more common. The plagioclase varies in composition and in many specimens shows zonal growths with acidic rims. One section of a zonal growth cut parallel to 010 gave extinctions of $+6^{\circ}$ to -23° measured against the 001 cleavage, indicating a variation from oligoclase to acidic labradorite. In general, however, the variation is not quite so great as this.

Biotite is evenly distributed throughout the rock, but much of it is altered, chiefly to chlorite, though in some degree also to epidote and muscovite. A specimen taken along Goodpaster River, just above the mouth of Indian Creek, illustrates well the formation of muscovite from biotite. The common accessory minerals are apatite, zircon, titanite, garnet, magnetite, and other oxides of iron. Secondary products in addition to chlorite, epidote, and sericite are calcite, pyrite, and hematite.

Any large mass of granitic or dioritic material in this area commonly contains a biotite granite facies. Biotite granite is found along the ridge between Coal Creek and Charley River, on the ridge between Birch Creek and North Fork of Birch Creek, on the ridge at the head of Buckskin Creek, on Hutchinson Creek, on a stream enter-

ing Salcha River from the south just below The Splits, and at many other localities. Much of the granite along Goodpaster River is also of this kind. Biotite granite occurs likewise in some of the larger dikes of the district.

Amphibole granite.—Through a decrease in the amount of biotite and an increase in the amount of hornblende, the biotite granite grades imperceptibly into hornblende granite. Hence many specimens show both biotite and hornblende. The biotite-hornblende granites are darker than the pure biotite varieties, mainly because they contain a larger proportion of femic minerals. As a rule it is not possible in the field to separate them from quartz diorites. In granularity they do not differ greatly from the other granites described, although those in which hornblende is the chief femic mineral may be a little coarser. As in the biotite granites, the feldspar is seen under the microscope to be largely orthoclase, with subordinate plagioclase having an average composition of basic oligoclase. Where hornblende is present titanite appears to be the most important accessory constituent. The other accessory minerals are apatite, magnetite, and zircon, and the secondary minerals epidote, calcite, and sericite. A specimen from a point $2\frac{1}{2}$ miles west of the junction of Manila Creek with Middle Fork of Fortymile River shows evidence of considerable metamorphism, which has resulted in the development of undulatory extinction in the quartz crystals and in the formation of myrmekite or secondary quartz and feldspar within the feldspars. Another specimen of particular interest, collected from the north side of Slate Creek where it joins the Fortymile, is a basic differentiate of the granitic magma, consisting largely of hornblende and biotite with subordinate quartz, orthoclase, and albite that show strain phenomena. The hornblende is zonally grown, being brown in the center and grading outward into the ordinary green variety.

Hornblende granite forms much of Veta Mountain and is found also on the spur between Ole and Independence creeks, on the spur between Pittsburg and Portage creeks, and at numerous other localities. It is not nearly so plentiful, however, as biotite granite.

One specimen—the only one found in the quadrangle—of a granite carrying pyroxene was obtained on the spur between Ole and Independence creeks about half a mile north and $2\frac{1}{2}$ miles east of the junction of the two creeks. This specimen, however, is not a true pyroxene granite, for the diopside which it contained was subordinate in amount to the hornblende and biotite. It is better described as a pyroxene-bearing hornblende granite.

Tourmaline granite.—At several localities in the area tourmaline-bearing granite has been noted. It does not have the general appearance from the hornblende granite, but it

sist of quartz, orthoclase, oligoclase, and tourmaline, accompanied in many specimens by muscovite, apatite, garnet, and zircon.

Epidote granite.—At one or two localities, notably on the spur northwest of the mouths of Comet and Champion creeks, granites containing considerable amounts of epidote have been found. The epidote is fresh looking, but the presence of calcite and chloritized biotite indicates that it is of secondary origin. Microcline and albite are the feldspars commonly developed.

MONZONITIC ROCKS.

A monzonitic type of granitodioritic rock occurs on the ridge between Mosquito Fork and Buckskin Creek, close to the east edge of the quadrangle. At this point rocks that consist of quartz, orthoclase, plagioclase, hornblende, biotite, titanite, apatite, and magnetite were found. The plagioclase varies from andesine to acidic labradorite, and is present in about the same proportion as the orthoclase. In the Fortymile quadrangle, just across the border, another specimen of the same type was found. These rocks are of interest chiefly on account of the fine examples of myrmekite which they afford.

DIORITIC ROCKS.

Granodiorite.—In association with the granitic and dioritic intrusives granodiorite has been found. Like the monzonite, however, it has been noted at only a few localities and is relatively unimportant. It contains less orthoclase than the monzonite and more than the quartz diorite, and thus, with the monzonite, it constitutes a transition from the granites to the quartz diorites. The plagioclase ranges from oligoclase to acidic labradorite. In other respects the granodiorite does not differ materially from many of the hornblende and biotite granites.

Quartz diorite.—In most hand specimens the quartz diorite and related rocks are darker than the granitic and monzonitic rocks, this being due to the larger amounts of femic minerals which the diorites as a rule possess. Several varieties of quartz diorite, depending on the character of the dominant femic minerals, have been noted, among them quartz-mica diorite, quartz-mica-hornblende diorite, and quartz-hornblende diorite. Quartz diorite porphyry has also been found. The primary minerals are quartz, plagioclase, orthoclase, biotite, hornblende, apatite, augite, titanite, magnetite, ilmenite, and zircon, and the secondary minerals sericite, epidote, zoisite, chlorite, calcite, pyrite, and quartz. Quartz and feldspar are the most plentiful, although biotite and hornblende commonly form an important part of the rocks. In general the fabric of these rocks is hypidiomorphic granular, but in some occurrences the feldspar and

locally both the feldspar and the quartz have developed in part as phenocrysts, giving rise to a porphyritic fabric. Augite is an accessory femic mineral and does not occur in quantities sufficient to form quartz-augite diorite. The plagioclase is characterized by well-developed zonal growths, most of which have basic centers and acidic rims. Extinction angles on 010 sections measured against the 001 cleavage gave from $+5^{\circ}$ to -25° , indicating compositions varying from oligoclase to labradorite. Where alteration has taken place, the zonal growths are usually more changed than the outer rims. The chlorite and sericite are derived largely from the biotite, and the epidote and zoisite are formed for the most part as alteration products of hornblende.

Quartz diorite occurs at many localities in the Circle quadrangle, both in association with more acidic intrusives and in large masses separated from the granitic rocks. With the more acidic intrusives, it is found along Goodpaster River, on the ridge at the head of Miller Creek, on the ridge at the head of Coal Creek, on the ridge east of Granite Creek, at the head of Shaw Creek, and elsewhere. More extensive occurrences are at Twin Mountain and West Point.

Diorite.—Two main types of diorite are developed in the region. The more plentiful is hornblende diorite, which consists essentially of feldspar and hornblende with a few crystals of apatite and pyrite. The feldspar is largely plagioclase with an average composition of andesine, although the zonal growths that characterize the rocks vary in composition from oligoclase to labradorite. Orthoclase is relatively unimportant.

The other type is the augite diorite, which differs from hornblende diorite in having augite and biotite in place of hornblende. Orthoclase is commonly present, although subordinate in amount to the plagioclase. The accessory constituents are apatite, magnetite, and titanite, with small amounts of secondary epidote.

No large bodies of true diorite have been found, but the occurrences noted are associated with larger bodies of dioritic and granitic rock. In the Circle quadrangle hornblende and augite diorites, like the monzonites and granodiorites, are doubtless to be regarded as facies of the granodioritic magma rather than as characteristic rock types.

GABBRO.

As a rock type gabbro is of little importance in the area under consideration. It is found in two or three places only, and is probably a differentiated facies of a more acidic magma. Specimens have been collected on the ridge at the head of Fisher Creek and at the junction of Shaw Creek with North Fork of Birch Creek. The specimens examined consist largely of feldspar and augite, with accessory magnetite and apatite. The feldspar is exclusively plagioclase, varying

somewhat in composition but averaging about the composition of labradorite. Chlorite is commonly present and is probably derived from biotite. In the specimen from Shaw Creek quartz was also found to be present, so that the rock from this locality is really a quartz gabbro. The gabbros differ from the augite diorites mainly in their total lack of orthoclase.

PERIDOTITE AND PYROXENITE.

Along the ridge at the head of Fisher Creek there is a body of peridotite of considerable size. The rock is a dunite and consists entirely of olivine, much of which is altered in part or wholly to serpentine.

Pyroxenites have been noted at several localities. At the junction of the two large streams which make up South Fork of Salcha River is an altered pyroxenite that consists entirely of pyroxene, probably augite, which has been altered subsequently to tremolite and tremolite asbestos.

On Joseph Creek, about $1\frac{1}{2}$ miles above Joseph village, specimens of pyroxenite were collected which in thin section are seen to consist largely of augite, with small amounts of hornblende, apatite, basic labradorite, and oxide of iron, probably magnetite. Some of the hornblende is probably of secondary origin, and calcite also occurs as a secondary product. One specimen was considerably mineralized by pyrite, which occurs along cracks, replacing augite. In this specimen the apatite was very noticeably biaxial.

Along the divide between Salcha River and Shaw Creek, about 10 miles south and $2\frac{1}{2}$ miles east of The Splits, a diallagite was collected, which consists essentially of diallage, with small amounts of olivine, tremolite, feldspar altered to chlorite, and magnetite.

Peridotites and pyroxenites have also been found at several localities in this region outside of the Circle quadrangle. About 20 miles southeast of the quadrangle, in the valley of Dennison Fork of Forty-mile River, lherzolite and websterite occur as inclusions in the basaltic lava of a small extinct volcano near the east branch of Dennison Fork.

METAMORPHOSED PLUTONIC ROCKS.

Granite gneiss.—Along the periphery of some of the larger granite masses granite gneiss is found. The gneissoid character can not well be attributed to regional metamorphism, for the main intrusive mass shows no evidence of such alteration. It is therefore probably the result of local metamorphism along the contacts. A few of the gneisses, however, show no signs of strain phenomena in thin section and are possibly of primary origin.

In composition the granite gneisses do not differ materially from the granite. Quartz, orthoclase and microcline

biotite, and hornblende form the essential constituents. Augite also occurs in some specimens. As accessory constituents garnet, apatite, tourmaline, magnetite, zircon, and titanite are developed. The secondary products are sericite, chlorite, epidote, and calcite. In general the quartz and feldspar show undulatory extinction caused by the strain which the rocks have suffered. The banded character of the gneisses is very apparent in all hand specimens and in many thin sections.

In addition to the granite gneisses along the edges of the large intrusive masses still older gneisses have been found. Augen gneiss occurs in considerable amounts at certain localities in the Birch Creek schist. It is granitic in character but differs from the gneisses previously mentioned in the amount of metamorphism it has suffered. The feldspars, as a rule, are drawn out in elongated "augen" and are more commonly microcline than orthoclase. In many occurrences the gneissoid banding closely approaches schistosity. These rocks are doubtless the metamorphosed representatives of earlier plutonic rocks.

Quartz diorite gneiss (metadiorite).—The dioritic rocks, like the granites, have undergone metamorphism in many places along the contacts of the large intrusive bodies. Different varieties occur among the gneissoid representatives as they do among the quartz diorites proper. In general, the gneisses differ from the quartz diorites chiefly in the strain phenomena exhibited by the quartz and feldspar and in the banded character of the rock. In addition, some of their plagioclase shows an inclination toward the combination of albite and pericline twinning. Some of the quartz diorite gneisses show evidences of primary gneissoid character.

VOLCANIC ROCKS.

DISTRIBUTION AND AGE.

The volcanic rocks of the region, as here grouped, include all the lava rocks resulting from volcanic or fissure eruptions, together with the aphanitic intrusive rocks of related origin. Like the plutonic rocks, these fine-grained rocks show acidic, basic, and intermediate varieties, but the acidic and basic rocks are more sharply separated and are of about the same relative importance.

Geographically, the unmetamorphosed volcanic rocks are of less importance than the plutonic rocks and show less variation in composition. Surface lava occurs in many localities in the region and it is possible that a great deal more of it was poured out and later removed by erosion. The large number of acidic and basic dikes in the quadrangle tend to ~~confirm~~ support this view. In at least one place around the head of ~~Chautauque~~ ~~the~~ be shown that the rhyolite porphyry

flows were connected with one or more underlying dikes. On the other hand, at the basaltic Dennison Fork volcano, outside of the quadrangle, the eruption was of the central type. It is therefore probable that both kinds of eruptive action were important in the volcanic history of the region.

The general strike of many of the dikes is north-south to northeast-southwest, and at the head of Charley River the surface flows also conform to this direction. This trend is almost at right angles to that assumed by the crystalline schists and plutonic rocks.

The volcanic rocks, as might be inferred from what has been said, differ in age from the plutonic rocks. In general, the dike rocks and surface flows are to be regarded as Tertiary or later, although, like the deep-seated rocks, they are not to be ascribed altogether to one time. They comprise both acidic and basic rocks, and it is probable that the two types are of different age. The basic rocks are so fresh and unaltered that it has seemed best to regard them as younger than the acidic rocks, which, further, appear in one or two places to have been cut by basic dikes, although this relation has not been definitely established. Both acidic and basic dikes, however, cut conglomerate regarded as of Cretaceous age, and it seems safe, therefore, to regard most of the volcanic rocks as subsequent to a portion of the Cretaceous at least and as probably belonging to the Tertiary period.

RHYOLITIC ROCKS.

The rhyolitic rocks are light colored and commonly porphyritic, with phenocrysts of quartz and feldspar. In hand specimens the groundmass is generally aphanitic, although it is often possible to tell the character of the dominant feldspar mineral. Many rocks of rhyolitic composition occur throughout the region.

The rhyolite and rhyolite porphyry of the region consist essentially of quartz, orthoclase, and acidic plagioclase, together with some dominant feldspar mineral and accessory minerals. The plagioclase varies in composition from albite to andesine, but has an average composition corresponding approximately to basic oligoclase. Some microcline occurs along with the orthoclase. The three essential constituents—quartz, orthoclase, and plagioclase—occur both as phenocrysts and as components of the groundmass, although not uncommonly the plagioclase occurs only in the groundmass. Many of the phenocrysts are corroded, showing the effects of magmatic resorption.

Biotite and muscovite are the commonest rock-forming feldspar minerals, occurring singly in some rhyolites but generally in combination. Two specimens show an altered pyroxene as the chief feldspar constituent, but alteration has proceeded too far to permit the original character of the pyroxene to be determined. As accessory constituents, apatite, iron, garnet, magnetite, ilmenite, and titanite are developed.

Chlorite, sericite, epidote, calcite, and pyrite are the common secondary minerals.

The fabric of the rhyolitic rocks is somewhat variable, depending chiefly on the content of glass. A complete range of fabrics from holocrystalline-porphyritic to vitrophyric has been found, but the perocrystalline porphyritic type is the most common. Where much glass is present many "Sphaerocrystallen" (circular areas showing aggregate polarization) occur in the glassy base. One or two of the more crystalline specimens show the development of typical flow structures.

As a rule the rhyolitic rocks are very little metamorphosed, although in many places they are much altered by general aerial and aqueous agencies. Only one specimen among those examined showed any considerable amount of metamorphism. In this rock, collected along the telegraph line about 6 miles west of the mouth of Liscum Slough, the phenocrysts of orthoclase have been much strained and drawn out, although they still retain the outlines of their crystal form. In addition, a decided schistose fabric has been developed. The phenomena of dynamic metamorphism in these rhyolites, however, are of purely local significance.

The rhyolites occur as flows, dikes, and tuffs. The sheets around the head of Charley and Goodpaster rivers are the best examples of the flows. The dikes occur in many localities throughout the field, but mostly in the vicinity of larger granitic bodies. One or two occurrences of true rhyolite tuffs have been found in the quadrangle, but except for their tuffaceous fabric and altered character they differ in no way from the other rhyolites.

DACITIC AND ANDESITIC ROCKS.

Dacites and andesites constitute the fine-grained rocks of intermediate composition. Like the rhyolites, they are commonly found in association with deep-seated rocks of the granodioritic magma, and they may well be regarded as the surface equivalents of the quartz diorites and diorites. In general the dacites and andesites are likely to be darker than the rhyolitic rocks; but in many occurrences they can not be discriminated except by microscopic examination.

Dacite.—Rocks of the dacite type consist essentially of plagioclase, orthoclase, quartz, and some dominant femic mineral, together with accessory minerals. Orthoclase is not always present in the mode, but many of the rocks are somewhat glassy, so that it can not always be said that potash is low when it does not appear in one of the rock-forming minerals. Dacite is generally porphyritic, most of the phenocrysts being plagioclase, orthoclase (if present), and minerals also occur in the groundmass.

The plagioclase varies considerably in composition, as in the quartz diorites. Sections parallel to 010 show extinctions varying in character from parallel to -18° on the 001 cleavage, indicating a composition from basic oligoclase to acidic labradorite. Most of the zonally grown feldspars which exhibit these variations have acidic rims and basic centers, and the rims commonly withstand alteration better than the centers. The chief femic mineral is biotite, though hornblende may be more conspicuous in the mode. Where it is, orthoclase is not likely to be present and the plagioclase is likely to be more basic. Apatite, augite, magnetite, zircon, and garnet occur as accessory minerals. Sericite, chlorite, epidote, and calcite are the chief secondary minerals. The sericite is derived both from feldspars and from biotite. Chlorite, however, occurs for the most part as an alteration product of biotite. Epidote results from the decomposition of both biotite and hornblende, but in one or two specimens it is accompanied by calcite as the alteration product of garnet.

The fabric of the dacitic rocks is rather diverse, depending on the physical conditions under which the rock solidified. Almost all these rocks are porphyritic, but they vary from ~~holo~~microcrystalline to vitrophyric. A specimen of hornblende dacite showed under the microscope a poikilitic fabric, with hornblende as the oikocrysts. Flow structures may also be seen here and there.

Dacitic rocks occur chiefly as dikes, which are distributed throughout the region, although they are not so plentiful as either the rhyolitic or the basaltic rocks. They seem to be more closely related to the rhyolites than to the basalts and diabases.

Andesite.—In general character and mode of occurrence the andesites do not differ materially from the dacites except in containing no quartz. They are rather scarce and do not merit any further mention.

BASALTIC AND DIABASIC ROCKS.

Basalt.—The basalts are dark gray to black fine-grained to aphanitic rocks. Some of them are megaporphyritic, though much less so than the more acidic volcanic rocks. Through extensive alteration they have been altered in some places to dark-green rocks that constitute a part of the so-called greenstones.

Under the microscope the basalts are seen to consist essentially of plagioclase and augite. Other minerals, such as olivine, quartz, hypersthene, biotite, and basaltic hornblende, appear here and there in considerable amounts, giving rise to different varieties of the rock. Magnetite and apatite are the accessory constituents. In addition, considerable amounts of glass are common. The chief varieties of the rock are feldspar basalt (the common variety), olivine basalt, and quartz basalt.

The plagioclase ranges from andesine to bytownite. Zonal growths measured on 010 sections have extinction angles of -7° to -34° on the 001 cleavage. It occurs usually in subhedral lath-shaped individuals. The augite occurs in angular grains between the feldspar. Not uncommonly weakly pleochroic crystals of hypersthene take the place of the augite, either in part or altogether. Biotite and basaltic hornblende occur less commonly. Quartz is abundant as anhedral grains in the groundmass or as phenocrysts showing resorption. Where resorption has taken place, the quartz is generally surrounded by a rim of glass, which is in turn surrounded by a rim of radiating monoclinic pyroxene needles. Where quartz has been observed, olivine is usually lacking. Considerable glass is generally present, and "Sphaerocrystallen" occur in the glassy base.

The fabric of the basaltic rocks varies considerably, depending largely on the amount of glass. One or two specimens are holocrystalline and show a true doleritic fabric. Others are dominantly glassy, with resulting vitrophyritic fabrics. Between these extremes intersertal and hypocrystalline porphyritic fabrics occur. Where the rock is porphyritic, olivine, augite, and feldspar may occur as phenocrysts.

The basalt occurs both as flows and as intrusive bodies. The Denison Fork volcano is the best example of extrusive lava. The intrusive dikes and plugs occur at many localities throughout the quadrangle.

Diabase.—Diabase occurs in part as an intrusive rock of Paleozoic age and in part as an intrusive rock of probable Tertiary age, associated with the basalts. The older diabases occur mostly as sills and larger intrusive bodies, which by metamorphic processes have been altered largely to greenstones and serpentine. Rocks of this type outcrop at numerous localities on both sides of the Yukon above Circle. A diabase butte rises at the headwaters of Salcha River.

The younger diabase rocks occur for the most part as dikes and do not differ materially from the basalts in mineral constituents. True diabase, quartz diabase, and olivine diabase occur, but as a rule the rocks are holocrystalline or very nearly so. In many dikes the plagioclase and augite are poikilitically intergrown, giving rise to the ophitic fabric. In others, however, the augite is less plentiful and a little glass occurs, causing the intersertal fabric. Like the basalts, the younger diabase rocks are fresh and but little altered. They have been found on Sheep Creek, Hutchinson Creek, Granite Creek, North Fork of Fortymile River, and elsewhere.

SUMMARY.

In the Circle quadrangle a considerable variety of igneous rock types have been found. They vary on the one hand from granites and quartz monzonites through granodiorites and diorites to gabbros,

peridotites, and pyroxenites; and, on the other hand, from rhyolites and dacites to andesites and basalts. In none of these rocks, however, have any minerals rich in alkalies been found, other than the ordinary feldspars. The rocks of the region then are predominantly derivatives of a granitodioritic magma.

The uniform presence of quartz is worthy of mention. In almost all the rocks examined quartz enters as one of the components of the mode, and rock types lacking in quartz are very sparsely represented. Monzonites and syenites have nowhere been found and diorites and andesites are very subordinate. Even many of the basalts, which in other regions ordinarily have no quartz, in the Circle quadrangle contain considerable amounts of it. This abundance of quartz fits in naturally with the absence of alkali minerals.

Another striking feature is the absence of the basic dikes that are so common in regions of similar intrusive rocks. Differentiation resulting in the production of such rocks does not seem to have taken place. The proportion of femic minerals in the plutonic rocks differs in different localities, resulting locally in the production of a rock wherein one of the femic minerals is the dominant rock-forming component. Some of the hornblende-rich granites and diorites illustrate this condition, but the relation of these rocks to the granitodioritic magma is plain, some one mineral being merely accentuated without any marked modification in fabric or mode of occurrence. On the other hand, differentiated acidic rocks, such as pegmatite and aplite, are common.

Regarded as a whole, the igneous rocks of the Circle quadrangle are of importance chiefly on account of their wide distribution. Although many varieties occur, yet no specialized rock types have been noted. The rocks in their general character resemble the igneous rocks in southeastern Alaska and in the Alaska Range.

CONTACT METAMORPHISM.

The intrusive rocks have complicated the structures of the intruded rocks, have indurated them, and have developed new minerals in them. The zone of influence, however, except around the deep-lying intrusions, has been comparatively narrow and has probably nowhere much exceeded 1,000 to 2,000 feet.

Where the deeper rocks have been intruded, new minerals, principally quartz, feldspar, garnet, staurolite, and biotite, have been developed, and generally a considerable amount of pegmatitic material has been formed in the shape of many small apophyses crosscutting the schists and lying parallel to their structure. Through this process the schists lose their identity and become granitized. Where the limestones have been metamorphosed they have become

in places garnetiferous. At one locality a large amount of diopside and some scapolite were developed.

Where the Paleozoic carbonaceous rocks have been intruded andalusite is the most common contact mineral. The greenstones and limestones appear to have undergone but little alteration, though the limestones in some places contain considerable colorless amphibole. The pegmatitic intrusions are apparently rare in the Paleozoic rocks. Numerous dikes, however, are typical of the contacts and many of them are parallel to the structure of the intruded rocks. In composition they resemble the main intrusive mass or form a somewhat more basic rock related to it. About the only effects noticed in their vicinity are fracturing and induration. In comparison with the large areas of intrusive rocks the amount of contact metamorphism observed is relatively small.

MINERALIZATION.

In some places considerable pyrite occurs in the rocks adjacent to the igneous masses, and in the Circle district both cassiterite and wolframite have been obtained in the Birch Creek schist close to the biotite granite.

It seems highly probable that the gold also in the Circle district is more or less closely related in its origin to the intrusive rocks. On Homestake Creek, just beyond the western edge of the quadrangle, gold has been found in highly mineralized schist next to the contact with a dike of granite porphyry. On Mosquito Fork, in the southeastern part of the quadrangle near the boundary, gold and considerable iron pyrites occur in a mineralized zone, with many small quartz stringers in quartz diorite. Fine flour gold is readily panned from the weathered material. The occurrence is apparently a silicified shear zone in the igneous rock. Assays of two specimens gave for one 0.58 ounce gold and 0.1 ounce silver and for the other 0.36 ounce gold and 0.1 ounce silver to the ton. At another locality on Mosquito Fork, near the mouth of Gold Creek, gold has been found in veins in close association with igneous rock. Adjacent to both eastern and western boundaries of the quadrangle, then, gold has been found in close association with igneous rocks, and it seems highly probable that these rocks were active agents in the mineralization and that the contacts of the intrusive rocks and the adjacent portions of the intruded rocks are the most favorable localities for prospecting.

That the granitic intrusive rocks caused the formation of many of the quartz veins in the schists and later rocks is shown by the fact that good exposures around intrusive masses (as on canyon walls) show the main intrusive body to be fringed with apophyses of more or less related composition which farther away give place to abundant

quartz veins, which in turn, still farther away, become less abundant and finally disappear, indicating that they bear a definite relation to the intrusive mass. For half a mile or more around many if not most of the intrusive bodies abundant quartz is present, and the facts seem to indicate clearly that it has resulted from the intrusion. The fact that intrusive masses occur within all the placer-mining districts and that auriferous quartz veins have been found most commonly in the vicinity of these masses suggests that the gold as well as the quartz had its origin in the process and products of intrusion.

STRUCTURE.

The complex structures characteristic of the sedimentary formations of the quadrangle have been rendered more complex by the extensive intrusions. The rocks have the two great prevailing structural trends so characteristic of much of Alaska—the southeast-northwest trend and the southwest-northeast trend. In the Circle quadrangle the southeast-northwest trend is the more apparent, but in places, especially toward the western margin of the quadrangle, the other trend, which is characteristic of the Fairbanks quadrangle, begins to assert itself.

In some places the sedimentary rocks have adapted themselves to the outlines of the igneous bodies and have bent round more or less in conformity to them. In other places they have been crumpled upon themselves or cut across by the igneous bodies.

The characteristic structure of the Birch Creek schist is one of closely appressed recumbent folds, the planes of whose axes are nearly horizontal. The rocks are much jointed and contain much lenticular quartz. The Paleozoic rocks also have been closely folded and in some places possess structures practically as complicated as those of the Birch Creek schist, though their original structures have not everywhere been so thoroughly obliterated. Cleavage is a rather characteristic structure.

The Mesozoic and in places the Tertiary rocks along the Yukon have also been closely folded. The Tertiary deposits, however, have not been so uniformly affected and in places are nearly horizontal.

A line connecting the Fairbanks and Circle districts apparently coincides with the axis of a large anticlinal area of the Birch Creek schist, flanked on both the northwest and southeast by Paleozoic rocks. The rocks flanking the northwest side bend round toward the southeast in the Crazy Mountains and extend across the northern edge of the quadrangle. The rocks flanking the southeast side parallel to some extent the belt on the northwest but are more complicated by the presence of intrusive masses. This second belt of Paleozoic rocks is bounded on the south by another area of schist that continues toward the southeast, flanking the large masses of igneous

rock that occur in that direction. This belt of schist narrows to about 6 miles between the igneous rock and Tanana River a few miles southeast of the quadrangle.

In general, then, the two Paleozoic synclinal areas, separated by an anticlinal area of schist, bend round from the northeast trend to take on the northwest trend. This deflection, which is one of the most striking facts in the geology of Alaska, is shown also in the Alaska Range, in the southern coast line of Alaska, and in the course of Yukon River.

GEOLOGIC HISTORY.

EVENTS TO THE CLOSE OF THE TERTIARY.

The material available for constructing a geologic history of the region is scanty and it is only possible to summarize what appear to be the most important geologic events.

The evidence indicates that the area is one of sedimentary rocks, thousands of feet in thickness perhaps but thin in comparison with those of the Yukon-Tanana region as a whole, overlying batholithic masses of granitic rocks that form an intrusive foundation.

The lithologic character of the oldest rocks, the Birch Creek schist, indicates uniformity of conditions over wide areas. The interbedding of arenaceous, argillaceous, and some calcareous material is common wherever these schists occur. The formation becomes apparently more calcareous toward the top, where both limestone and carbonaceous schists are likely to be found. The apparent thickness of these deposits indicates a long continuance of conditions favorable for their deposition. The presence of gneissoid granites in intrusive relation to these schists indicates that the consolidation and folding were accompanied by the intrusion of granitic material which later underwent metamorphism along with the intruded rocks. The rocks become gneissoid with increasing depth, toward the intrusive contact. The top of the schists is regarded as unconformable to the Paleozoic on account of their prevailing greater metamorphism and their greater complexity of folding. The relations of the two, however, are nowhere clearly shown, being apparently obscured by welding and by metamorphism in the lower portion of the Paleozoic.

The Paleozoic was an era of great variation in conditions within somewhat narrow limits. Quartz feldspar and other siliceous sediments form an important part of the geologic section, but the prevailing sedimentary rocks are argillaceous, with abundant limestone and greenstone. The dominant characteristic of the Paleozoic is its abundant volcanic material. In some areas volcanic action commenced apparently near the beginning of Paleozoic time and con-

tinued at intervals until it reached a maximum, perhaps in the Middle Devonian. Diabasic and basaltic flows, tuffs, and breccias in close association with limestones of the Devonian are particularly abundant and indicate widespread volcanic activity during that part of the Paleozoic era. The Paleozoic areas in the Fairbanks quadrangle indicate that although the variation in sedimentation was great there was no appreciable stratigraphic discontinuity between the Ordovician, Silurian, and Devonian. Ordovician fossils occur in conglomerates underlying limestone and in the limestone itself near the base; farther up in the same body of limestone Silurian fossils occur; and still higher up fossils that have been determined as Devonian are found.

The Carboniferous is characterized by a large amount of limestone. So far as known only the upper Carboniferous appears within the Circle quadrangle, but further work may reveal the extension into it of other Carboniferous formations that lie just beyond its eastern limit. Deep-sea conditions prevailed during the deposition of the upper Carboniferous and fossils are abundant in its limestones.

The Lower Cretaceous was an epoch of shale and sand deposition, which was closed by extensive mountain making and abundant intrusion of granitic rocks that continued till the end of the Mesozoic. In the Rampart country the Upper Cretaceous has at its base a conglomerate composed of fragments of the underlying rocks which are regarded as in part Paleozoic and in part Lower Cretaceous. The Upper Cretaceous, therefore, is in part at least unconformable to the underlying rocks. Shore conditions are indicated in the Charley River region by the coarse conglomeratic rocks regarded as Upper Cretaceous, and also in the Rampart country, where dicotyledonous leaves and ammonites occur in close association in the Upper Cretaceous.

The Tertiary rocks include clay, sand, and lignites with abundant plant-bearing beds and indicate that Tertiary deposition began in an area of low relief where sluggish streams, lakes, and swamps prevailed. The later conglomeratic deposits, which are probably in the main of fluvial origin, indicate a change of conditions that resulted finally in the rather close folding of many areas of Tertiary rocks.

The main events to the close of the Tertiary may be summarized as follows: Deposition of arenaceous, argillaceous, and some calcareous beds over wide areas; consolidation, elevation, folding, intrusion of granitic rocks; metamorphism; erosion; Ordovician, Silurian, Devonian, and Carboniferous deposition during which much basic material became interbedded with the sediments through the agency of the volcanic phenomena so characteristic of the Paleozoic; Lower Cretaceous deposition; abundant granitic intrusion throughout

a large part of the Mesozoic continuing till the close of the Upper Cretaceous; volcanic phenomena producing rhyolitic, dacitic, and some basaltic rocks, probably accompanied by the intrusion of granitic rocks and lasting into the Tertiary and later; deposition, elevation, and folding of fresh-water Tertiary deposits.

DEVELOPMENT OF THE PRESENT SURFACE.

The plateau.—The development of the present surface during Pleistocene and Recent time has been complex and is very probably due to several processes. The lithologic character of the older formations indicates that during periods of erosion the surface became more or less reduced to a lowland of faint relief, and probably this has been the history of the portion of the present surface known as the Yukon Plateau. This plateau was described on pages 13-14 as the uniform level above which extended numerous ridges and domes and below which the valley systems had been cut. Its elevation is about 4,000 feet near the heads of Goodpaster and Charley rivers and about 3,000 feet in the vicinity of the Yukon and Tanana. It is one of the most conspicuous features of the relief in the interior of the Yukon-Tanana region. After its formation it was uplifted to its present altitude, so that rejuvenation of the streams tributary to the Yukon is general, and narrow canyons of the lower valleys, like those of Birch Creek, Charley River, and Fortymile River, are characteristic, as are also the open flat valleys that form the upper portions of the valleys of the same streams. As the present valley of the Yukon has been intrenched in an older valley floor, so the present canyons of these streams have been cut in older valley floors whose remnants appear as well-developed benches along their sides.

On the lower benches gravels are still present, but on the higher benches, like that of the Seventymile, 500 feet above the present stream, no gravels were observed. There seems little doubt, however, that this bench belongs very definitely to the history of the Seventymile Valley. It seems most reasonable to regard the still higher general level of the plateau as having been developed under former drainage conditions and as having later been elevated and subjected to great dissection, just as the benches of present streams are cut by minor tributaries into many fragments.

The larger irregularities of the surface above 4,000 feet are due predominantly to the presence of the more resistant igneous rocks that have withstood erosion. Among the minor details of form are the cirques, U-shaped valleys, and morainal deposits that have already been described as products of local glaciation. (See p. 34.)

Step-cut hills.—A feature that is very common in portions of the area was briefly described as follows by the writer¹ in the description of the Seventymile drainage area in 1905:

The hills rise to a height of 2,500 feet or more above the river and exhibit beautifully preserved rock-cut benches to their summits, which are flat topped, several acres in extent, and often correspond in level to the truncated tops of neighboring hills. The benches, except where obscured by gulches, can be traced around the hills; they are especially prominent on the spurs and occur at corresponding levels. The vertical distance between the steplike benches varies from a few feet to about 50 feet, the rise from one to the other often showing an outcrop of the bedrock. The rocks comprising this area are highly contorted metamorphic schists and granular intrusives. Whatever the bedrock or its attitude, the same forms have been developed and are most striking features of the landscape. Similar forms were observed in other localities on the northern side of the Yukon-Tanana country but nowhere exhibited such development as in the valley of the Seventymile.

Since 1905 similar step-cut hills have been observed in different parts of the Fairbanks region, where they are most prominently developed at 4,000 to 5 000 feet above sea level. The truncated domes, the many benches at apparently concordant elevations on the spurs of the ridges, and the flat passes through ridges form perhaps the most striking topographic detail in the quadrangle.

Under present conditions there seems to be no adequate cause that could produce such uniform results at approximately concordant levels over widely separated areas on spurs extending in different directions.

The efficacy of ice in developing flats in portions of river valleys has been noted, and it is very probable that snow banks have, to a considerable degree, the same kind of efficiency in protecting the surface beneath and in localizing erosion to the area in contact with the edge of the snow bank. The snow could thus protect from erosion forms already present and might even accentuate such forms. The snow banks lingering in the angles between different slopes would localize the erosion at the inner edges of the benches and maintain the sharpness of angle already existing. It seems reasonable, therefore, to conclude that the forms under consideration were produced by former drainage conditions and have been protected and even kept in repair by snow banks.

GOLD IN THE YUKON-TANANA REGION.

GENERAL FEATURES.

The Yukon-Tanana region has been known chiefly for its production of placer gold, which up to the present time has amounted to approximately \$75,000,000. Most of this has come from the Fair-

¹ Prindle, L. M., The gold placers of the Fortymile, Birch Creek, and Fairbanks regions, Alaska: Bull. U. S. Geol. Survey No. 261, 1906, p. 20.

banks district, the other chief producing areas being the Fortymile, Circle, and Rampart districts.

Most of the gold of the Fortymile district and all that of the Circle and Fairbanks districts has been derived from areas in which the Birch Creek schist forms the bedrock. Most of the gold of the Rampart district has been derived from areas where Paleozoic rocks form the bedrock. Some of the gold found on streams tributary to the Yukon above Circle has apparently been derived from quartz veins in Lower Cretaceous slates. At other localities in this region the gold has been derived from areas of Tertiary auriferous conglomerates.

In the Fortymile district gold has been found at one locality in place in quartz diorite and at another locality in Paleozoic rocks close to the contact with quartz diorite. Several sedimentary and igneous formations are known to have been sources of placer gold.

The origin of the gold is indicated by the fact that in all the most productive areas igneous intrusive rocks are present and the finding of gold in bedrock near them indicates that they are its chief source.

Placer gold is found in bench gravels at elevations not exceeding 500 feet above the present streams and also in the stream gravels, where it is almost invariably close to bedrock.

GOLD IN BEDROCK.

Birch Creek schist.—The occurrence of gold in the Birch Creek schist has been studied in the Fairbanks district, where the auriferous quartz veins range from small stringers to veins 15 feet or more in thickness. The richest portion of the veins that have been prospected, however, is as a rule not more than a foot thick. The veins strike in general northeast and southwest, about parallel with the strike of the country rock. They are generally almost vertical, in places parallel with and in places cutting the structure of the schist. The auriferous quartz is generally white and opaque; the barren quartz is gray and glassy. Most of the gold is associated with arsenopyrite and stibnite. Other associates are iron pyrites, limonite, galena, and sphalerite. Minerals in the stream gravels that have apparently been derived from similar veins are cassiterite, wolframite, and bismuth.

In the Birch Creek district, on Deadwood Creek, cassiterite and wolframite have been found associated with gold in the placers. On Eagle Creek there is a thin vein of gold in mica schist associated with some quartz.

The gold found in quartz veins is described by Brooks ¹ as follows:

A general wide distribution of vein quartz is attested both by the bedrock exposures and by the character of the fluvial deposits. This quartz is very frequently found to be iron stained, and one naturally turns to it to seek a source of the placer gold. There is but little direct evidence on this point. The presence of pyrite-bearing vein quartz in the auriferous alluvium is a characteristic feature of these deposits. On Eagle Creek a 4-foot gold-bearing quartz vein is said to have been encountered in the drift mining, but the writer did not see the exposure, as the drift had caved in. A specimen of the quartz showed it to be iron stained and broken by thin seams of gold. The gold of the adjacent placer was angular and carried much quartz. A mineralized fracture zone about 8 inches in width has been found on the upper part of Deadwood Creek. Within this zone the schist is permeated by stringer veins carrying pyrite and galena, and it is reported to carry values of \$6 in gold and \$8 in silver.

Spurr ² reported the finding of gold-bearing quartz on Harrison Creek. He describes the occurrence as follows:

"The best example of gold-bearing quartz found in the gravel is a rhomboidal block of quartz schist, about 4½ by 5 by 2 inches, found on claim 91, on North Fork, about three-quarters of a mile above the forks. On one of the larger surfaces of this block is a quartz vein which is richly spotted with flakes and specks of gold, ranging from three-sixteenths of an inch in diameter to mere specks, which finally become invisible to the naked eye."

These facts indicate that the placer gold is derived from zones of mineralization in the schist series. The wide distribution of the placer gold is not a favorable indication that the values are sufficiently localized in the bedrock to afford commercial ore bodies. It must be said, however, that there is little evidence on this point, and workable lodes may yet be found when a systematic search is made.

Paleozoic rocks.—Placer gold in Paleozoic areas has been found mainly in the Rampart district, where it has apparently been derived from quartz veins in carbonaceous slates. Cassiterite is commonly associated with the gold in the placers.

In the Chicken Creek valley, in the Fortymile district, gold has been found in small calcite veins in rocks regarded as Paleozoic close to an igneous contact.

On creeks tributary to the Yukon above Circle, Brooks observed a close relation between the alluvial gold and Lower Cretaceous slates, describing it as follows: ³

The rocks exposed along the Yukon between Eagle and Circle do not anywhere include any of the older schists, such as are associated with the Birch Creek placers. In fact, over much of this belt the formations are slightly altered limestones, shales, slates, and conglomerates, which do not bear evidence of mineralization and will not attract the placer miner. Locally, however, some of these rocks are mineralized and contain more or less gold. Thus on Nugget Gulch, a tributary of Washington Creek, slates of Cretaceous age are found which are permeated with quartz veins, some of which must yield gold, as the associated alluvium is auriferous. The writer was not able to study this locality, but it appears that the coarse gold occurs in small patches

¹ Brooks, A. H., Bull. U. S. Geol. Survey No. 314, 1907, pp. 189-190.

² Spurr, J. E., Geology of the Yukon gold district, Alaska: Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1896, pp. 353-354.

³ Brooks, A. H., op. cit., pp. 198-199.

on the bedrock. This occurrence, though probably of small commercial import, has a far-reaching significance, as it indicates that there has been an intrusion of mineralized veins since these younger rocks were deposited. The writer is, however, of the opinion that this mineralization is not general enough to encourage the search for placers where these Cretaceous slates form the country rock.

Tertiary rocks.—In the area just described are gold-bearing stream valleys that lie entirely in areas of Tertiary conglomerate, indicating that the gold was present either in the conglomerate or in some alluvial deposit that may have overlain the conglomerate and may have been for the most part removed. The boulders mentioned on page 33 include vitreous massive quartzite and hard Paleozoic conglomerate. Their position in the Tertiary conglomerate is not definitely known. Mining has shown that they are rather common in the gravels of the present streams. They have not been observed by the writer except near the summits of the ridges where the Tertiary conglomerate occurs—that is, near what is apparently the highest portion of the conglomerate—and in these positions they occur only as loose boulders among weathered material, so that it was impossible to determine whether they formed a constituent of the conglomerate or of a deposit of high gravels coarser than the conglomerate. However, in view of all the facts available, it seems probable that these boulders formed a part of the conglomerate, probably about its highest part, and that the placer gold in the creeks was deposited with the gravels of the conglomerate rather than derived from a bed of alluvial deposits that formerly may have veneered the area in which the placers occur. Nevertheless, in considering the origin of the placer gold the possibility of its derivation from high-lying gravels that have in part been removed and in part merged with the weathered conglomerate can not be left out of consideration. As more detailed work is done further facts bearing on the problem may be discovered.

The material of the conglomerate has been derived from the older rocks, which have in places been auriferous. It would be perfectly natural, therefore, for placer gold to be present in the conglomerate, perhaps irregularly distributed and nowhere concentrated or perhaps confined to some particular horizon. However, even if confined to a particular horizon it was probably not sufficiently concentrated to form deposits of economic importance.

Igneous rocks.—The occurrence of gold in the quartz veins and silicified areas in the quartz diorites of Mosquito Fork has already been described. (See pp. 49–50.)

Primary source of gold in bedrock.—Igneous rocks are present in all the chief placer-mining districts of the region and are generally close to localities where gold has been found in bedrock. They have been active agents in opening the rocks to the influence of percolating solutions and have supplied heat to maintain for a long period the

mobility of materials by keeping them in solution. The hot springs which are common close to granitic masses in different parts of the Yukon-Tanana region indicate the long continuance of the heat derived from igneous rocks. The point might be raised that important placers have been found only in the vicinity of small areas of igneous rocks and not around large areas like those present in the Circle quadrangle, and it is possible that the conditions for deposition are more favorable around the smaller masses. The same fact has been observed in California.¹ The most important mineralization apparently took place in the later part of the Mesozoic era.

PLACER GOLD.

Placer gold occurs in bench gravels and in the gravels of the present streams. The bench gravels occur at elevations not exceeding 500 feet above the level of the present streams, and but few of them have been found rich in placer gold. Most of the gold is found in the deposits of the present streams. These deposits vary greatly in thickness. Most of those of the Fortymile and Circle districts, and a part of the Rampart district, are comparatively shallow, and most of those of the Fairbanks district are deep, some of them measuring more than 300 feet. The greatest part of the alluvial deposits are more or less permanently frozen, in places to depths of more than 300 feet, but the distribution of frozen ground is irregular, depending on drainage conditions. In the Ester Valley, in the Fairbanks district, for example, about 100 feet seems to be the limit of the frost; below that level a large amount of live water is present in the gravels.

The stream deposits are generally separable into an upper layer of fine clayey and sandy material known as "muck," an intermediate bed of barren gravel, and a lower bed of auriferous gravel, ranging from a few inches to 6 feet or more in thickness. The productive gravels are almost invariably next to bedrock. Most of the gold is found close to bedrock, or, where this is blocky, in cracks and crevices to a depth of a foot or even 3 feet or more. The width over which the gold is found in sufficient quantity to pay for working under present conditions ranges from a few feet in the narrow valleys to several hundred feet in some parts of the wider valleys. The average width for the Fairbanks district is about 150 feet. In exceptional valleys, like that of Cleary Creek in the Fairbanks country, the productive gravels have been found to be continuous throughout the length of the valley.

¹ Lindgren, Waldemar, *The Tertiary gravels of the Sierra Nevada of California*: Prof. Paper U. S. Geol. Survey No. 73, 1911, p. 65.

GOLD IN THE CIRCLE QUADRANGLE.

The bulk of the gold from the Circle quadrangle has been obtained in the Birch Creek district. A small amount is obtained annually from creeks tributary to the Yukon above Circle and a little has been obtained from the Seventymile, Fortymile, Salcha, and Chena drainage areas.

BIRCH CREEK DISTRICT.

GENERAL FEATURES.

Since its discovery in 1894 the Birch Creek district has been a continuous producer of placer gold. It has held its own in spite of discoveries made in other regions, and with the introduction of new methods of mining it is still maintaining its production. The following table shows its annual gold production from 1894 to 1911, inclusive, and the amount of silver contained in the gold.

Production of gold and silver from Birch Creek district, 1894-1911.

Year.	Gold.		Silver.		Year.	Gold.		Silver.	
	Quantity.	Value.	Quantity.	Value.		Quantity.	Value.	Quantity.	Value.
	<i>Fine ounces.</i>		<i>Fine ounces.</i>			<i>Fine ounces.</i>		<i>Fine ounces.</i>	
1894.....	493.75	\$10,000	123	\$77	1894.....	9,675.00	\$300,000	3,144	\$1,828
1895.....	7,255.25	150,000	1,886	1,226	1895.....	9,675.00	300,000	3,144	1,918
1896.....	23,862.50	700,000	8,794	6,080	1896.....	14,512.50	500,000	3,773	2,666
1897.....	24,187.50	800,000	6,289	3,773	1897.....	9,675.00	300,000	3,144	2,076
1898.....	19,350.00	400,000	5,031	2,908	1898.....	8,465.03	175,000	2,212	1,166
1899.....	12,038.75	250,000	3,144	1,886	1899.....	10,884.37	225,000	2,830	1,472
1900.....	12,038.75	250,000	3,144	1,886	1900.....	10,884.38	225,000	2,830	1,528
1901.....	9,675.00	300,000	2,512	1,507	1901.....	16,931.26	350,000	4,402	2,383
1902.....	9,675.00	300,000	2,512	1,331					
1903.....	9,675.00	300,000	3,144	1,668					
						229,055.63	4,735,000	58,914	37,212

The creeks of economic importance in the Birch Creek district flow from the ridge between the valleys of Crooked Creek and North Fork of Birch Creek and include tributaries of both. The principal gold-producing creeks tributary to Crooked Creek are Deadwood, Mammoth, Mastodon, Independence, and Miller; those tributary to Birch Creek are Eagle (with its tributary, Mastodon Fork) and Harrison. Several other creeks have produced small amounts of gold.

These areas have been visited frequently by parties from the Geological Survey and have been described in reports named in the list of publications. (See pp. 10-11.) These reports have been freely drawn upon in the preparation of the following description:

Most of the valleys are similar in development, having about the same length, width, and grade and carrying about the same amounts of water. Deadwood, Mastodon, and Miller valleys are all limited

on the east by a steep slope (Pl. XIII, A), close to whose base the streams flow over a flat having a maximum width of a few hundred feet. West of the flat is a gradually rising slope more or less benched, a few hundred feet to a quarter of a mile in width, which merges with the gradually sloping ridges that form the west sides of the valleys. This unsymmetrical type of valley is very common. On some crests where the stream gravels have been worked out mining has been attempted on the benched slopes, and some productive ground has been found.

All the placer ground is within areas where the Birch Creek schist forms the bedrock. Some local intrusions of porphyritic biotite granite and a few basic dikes are present.

The gravels, which are composed entirely of the varieties of bedrock outcropping in the valleys, consist mostly of subangular and angular fragments of quartzite schist and quartz-mica schist and considerable vein quartz. Most of the pieces are small, not exceeding a foot in diameter, and are mixed with finer material of the same nature. The proportion of boulders is small. The thickness of the deposit ranges from a few feet to 30 feet, but where most of the mining has been done generally does not exceed 8 feet.

The gold is found mostly close to bedrock, and the ground has been mined to a width of over 200 feet. Most of the gold is rather fine, the coarsest nuggets found weighing only 3 to 4 ounces. Considerable areas have yielded about 25 cents to the square foot of bedrock. Other areas, however, have yielded much larger amounts, and in 1903 some of the ground was reported to average \$1 to \$2 to the square foot. The average value of the gold has been reported by miners to be \$17.73 an ounce. That from Eagle Creek has a somewhat higher value.

PLACERS.

DEADWOOD CREEK.

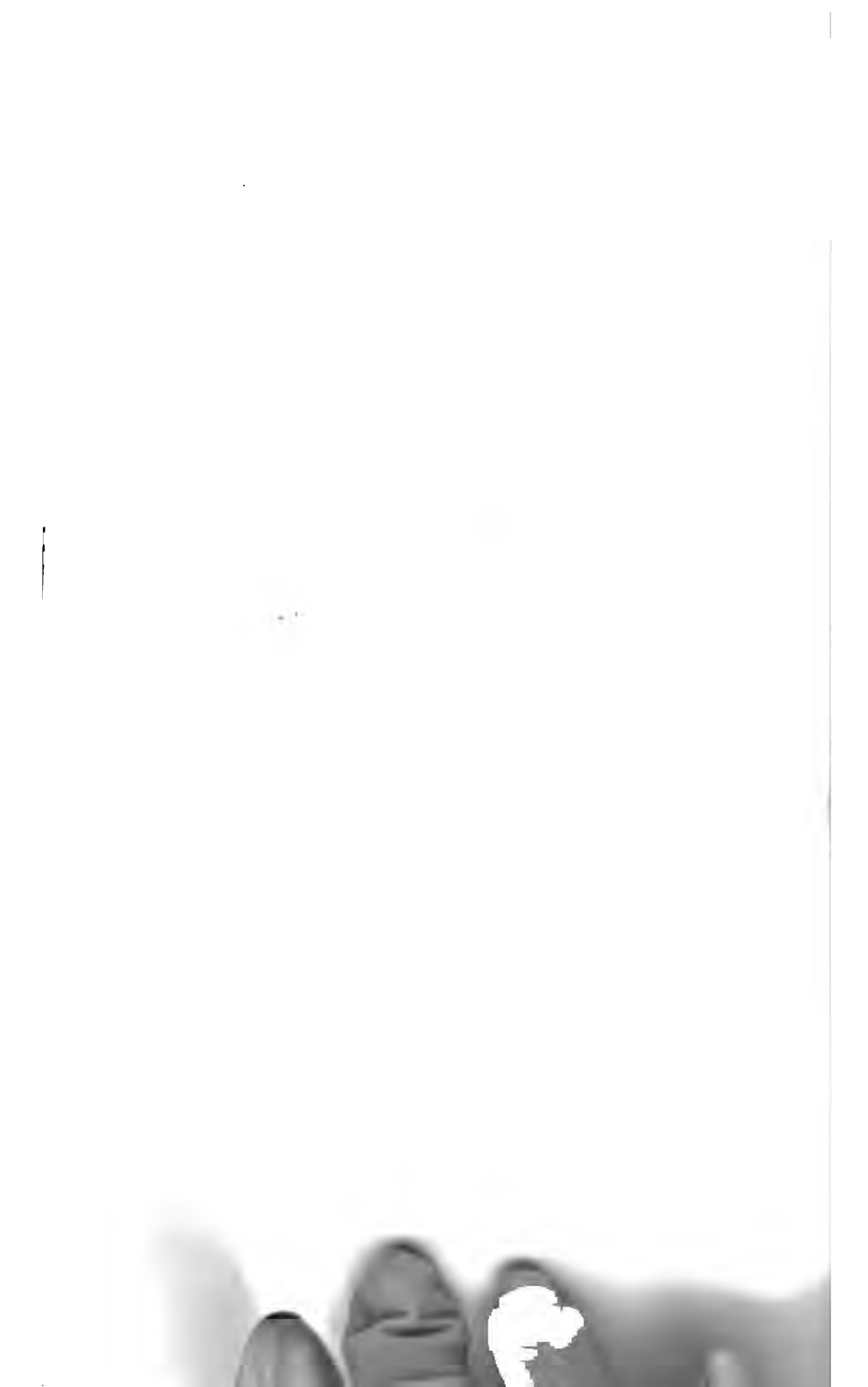
Deadwood Creek, which is about 20 miles long, heads in a ridge over 3,000 feet high and enters Crooked Creek at an elevation of less than 1,000 feet. Its valley is divided into two portions—an upper narrow portion about 12 miles long, and a lower portion about 8 miles long, where the valley merges in that of Crooked Creek. The stream flat, which in places is several hundred feet wide, is close against the steep east side of the valley. A more or less well-defined bench with a maximum width of several hundred feet rises gradually on the west from a level about 20 feet above the stream. Switch Creek, the most important tributary, is about 3 miles long and enters Deadwood Creek through a narrow V-shaped valley about 3 miles above the point where the main stream leaves the hills.



A. VIEW DOWN MASTODON CREEK.



B. VIEW UP EAGLE CREEK.



The bedrock in most of the valley is rather massive, blocky quartzite schist and quartz-mica schist. The rocks show minor folding and contain numerous small quartz stringers. Intrusive granite is very conspicuous in the region farther east, especially on Ketchum Creek, only a few miles east of Deadwood Creek, where weathering has carved it into some very striking pinnacled forms. On Deadwood Creek it is not so conspicuous, but forms the bedrock for about a mile. Near the mouth of the valley a diabasic dike was observed.

The gravels are composed of the varieties of rock mentioned. They consist of subangular fragments, mostly under a foot in diameter, more or less irregularly arranged in much finely broken material of the same nature. The depth to bedrock in the creek ranges from 3 to 12 feet and on the bench to the west, so far as known, from 6 to 20 feet. The gravels in the creek have a maximum thickness of about 8 feet and lie beneath a generally thin overburden. Some gold is found through the whole thickness of gravel, but most of it lies close to bedrock or in bedrock to a depth of 2 feet or more. Where the bedrock is massive and is divided into blocks through jointing, gold may have penetrated to a depth of 4 feet along the joint planes. The width of the pay gravel ranges from about 25 to 300 feet, the average being 175 feet. The average tenor of the ground for the entire creek is said to have been about 25 cents to the square foot of bedrock, but some ground has averaged much more, 50 cents to more than \$1 per square foot having been obtained. Little is known of the extent or tenor of the gravels of the bench. In a few places, however, gold has been found, and at one locality it was reported to average more than \$1 to the cubic yard of dirt moved. Two nuggets worth \$8 and \$10 were found. The gold on the creek is generally flattened and at the entrance of the valley is rather flaky; the largest piece recorded was valued at \$122. That found on the bench is rougher and thicker.

More than a hundred 500-foot claims have been staked on Deadwood Creek and more or less work has been done on about 70 of these. Gold has been found in commercial quantities from a point about a mile above the mouth throughout the length of the creek. Switch Creek also carries pay gravel. Nearly all the mining on Deadwood Creek has been done by small operators using simple methods. In the lower mile of its course, where its valley broadens and gradually merges with that of Crooked Creek, the gold is more disseminated and is not susceptible to profitable exploitation by crude hand methods. This part of the field is worthy of careful examination by those looking for dredging ground. At a point half a mile above the mouth of the valley the depth to bedrock is only 10 feet. It does not seem probable that the bedrock floor slopes more than

25 feet to the mile, and therefore it is not to be expected that the depth to bedrock between this point and the mouth of the valley will be found to be more than 35 feet.

Among the minerals associated with the gold are wolframite and cassiterite. The occurrence of these minerals in the placer deposits of Deadwood Creek was studied in 1909 by Johnson,¹ who says:

No exposures of the wolframite or cassiterite in place were seen. A small wolframite-bearing vein was reported to have been found in a prospect hole, sunk while prospecting the high-bench gravels for gold, on the high bench west of Deadwood Creek, near the junction of Deadwood Creek and Discovery Gulch. At the time of the writer's visit this prospect hole had caved in and was filled with water. No wolframite could be found on the dump.

Wolframite and cassiterite occur most abundantly in the placer gravels of Deadwood Creek a short distance below the mouth of Discovery Gulch. Concentrates collected from the sluice boxes here are composed principally of these two minerals. Placer wolframite is also reported from Discovery Gulch. It is not known to occur in the stream gravels of Deadwood Creek above the mouth of this gulch, nor has any been detected in the examinations of the concentrates collected above this point. It is not known whether these minerals are present in the high-bench gravels. The placer wolframite is found on all the creek claims on Deadwood Creek for at least 4 miles below Discovery Gulch, but it is not as plentiful on the lower claims as above the mouth of Switch Creek. The coarsest and most abundant wolframite and cassiterite are found on the west side of Deadwood Creek, a short distance below Discovery claim. The wolframite occurs in water-worn cleavage fragments, with slightly rounded edges. The color and streak are both dark brown. The largest piece seen measured 1.7 by 0.8 by 0.8 inches, but pieces three times as large as this are reported to have been found. The largest piece of cassiterite observed in the concentrates measured 1 by three-fourths by one-half inch. Most of the concentrates collected, however, passed through an 8-mesh sieve.

Concentrates from several claims on Deadwood and Switch creeks were examined. Associated with the gold in the concentrates were found wolframite, cassiterite, magnetite, ilmenite, arsenopyrite, pyrite, galena, limonite, garnet, tourmaline, and quartz. Wolframite was not detected in the Switch Creek concentrates. Cassiterite was found in all the concentrates examined, but most abundantly in those from Deadwood Creek between Discovery Gulch and Switch Creek. Magnetite was very abundant in the Deadwood Creek concentrates, but nearly absent from those collected on Switch Creek. The sulphides—arsenopyrite, pyrite, and galena—were found principally on Switch Creek.

BOULDER CREEK.

Placer gold has been found on Greenhorn Creek, a small tributary of Boulder Creek. The ground is shallow, but lack of water has prevented mining.

MAMMOTH CREEK.

Mammoth Creek has a broad flood plain 100 to 500 yards wide. The bedrock is chiefly schist but is cut by a continuation of the granite of Kechum and Deadwood creeks. The granite forms boulders

¹ Johnson, B. L., Bull. U. S. Geol. Survey No. 442, 1910, pp. 246-248.

4 or 5 feet in maximum diameter. The slope of the bedrock is low. The alluvium is from 10 to 15 feet deep, most of it being about 10 feet. The upper 2 to 3 feet is overburden. The gold is rather fine and is reported to be rather uniformly distributed.

INDEPENDENCE CREEK.

Considerable gold has been taken out of Independence Creek. The valley floor is about 100 yards wide at its mouth, but narrows sharply upstream. The distribution of productive ground appears to be irregular and to swing from one side of the creek to the other. The gravels are from 3 to 9 feet deep. Some well-defined benches are present.

MASTODON CREEK.

The headwaters of Mastodon Creek are gathered from an amphitheatral area on the northern slopes of Mastodon Dome, 4,400 feet high, about 7 miles southwest from the point where the creek enters Mammoth Creek. The valley is bounded by even-topped spurs, which slope gradually in a direction parallel to the creek at an altitude of about one-fourth mile above it. The valley is unsymmetrical in cross section, the stream in its lower portion flowing near the steep ridge on the east and being bounded on the west by a bench that rises with a steep grade to the base of the spur. The valley floor is about 400 yards wide at its mouth, and gradually narrows to about 200 yards 2 miles above.

Quartzite schist and mica schist containing many small quartz veins are the most common varieties of bedrock. Small granitic dikes also occur. The strike of the schistosity is usually across the stream and the dip is to the south.

The gravels include subangular fragments of the bedrock, fine material of the same nature, and some sand and clay. Much of the gravel is but little worn and its arrangement is generally more or less irregular. The average depth to bedrock is 10 or 12 feet, the maximum about 20 feet. In some places muck, which attains a thickness of about 4 feet, lies on top of the gravels. The maximum of overburden is about 7 feet. In some places the gold is scattered through the gravel and in others it lies close to bedrock or a few feet within it. It is generally rather fine, the coarsest piece found thus far weighing only 3 or 4 ounces. It is reported to assay from \$17.35 to \$17.38 per ounce. Some of the ground averages \$2 to \$3 a cubic yard and some of it is considerably richer. The lowest 2 miles of the valley is the richest portion and contains the largest body of productive gravels, which attain in places a width of 200 feet.

MILLER CREEK.

The valley of Miller Creek is similar in its essential features to that of Mastodon Creek. The unsymmetrical character is particularly well developed, the steep east side of the valley so overshadowing the upper portion of the creek that the ice lingers there till late in the season and prevents mining operations.

The bedrock consists of quartzite and quartzite schist veined with quartz. Granitic dikes occur on the divide between Miller and Eagle creeks. The gravels are similar in character and arrangement to those on Mastodon Creek. The depth to bedrock varies from 8 to 16 feet, of which 4 to 8 feet is overburden. In a few places a clay, which has been found to be as much as 3 feet in thickness, intervenes between the gravels and bedrock and contains most of the gold.

The gold is about the same as that of Mastodon Creek. Pieces weighing an ounce have been found, but most of it is rather fine. That near the head of the creek is rough. The gold is scattered through several feet of gravel over a maximum width of about 50 feet. Some of the ground has averaged about \$1.20 to the cubic yard. The creek has never been a large producer but has been worked more or less continuously since 1895.

EAGLE CREEK AND TRIBUTARIES.

Two small streams, Mastodon and Miller forks, unite to form Eagle Creek, a tributary of Birch Creek. Mastodon Fork heads on the northwest slope of Mastodon Dome and flows through a narrow V-shaped valley about 3 miles long to Miller Fork. The bedrock and gravels are similar to those of the other creeks described. As on Miller Creek, clay is in many places found next to the bedrock of quartzite schist. The depth to bedrock ranges from 8 to 10 feet or more, there being in some places 3 to 4 feet of overburden and 4 to 5 feet of productive gravels. Where clay occurs along with the gravels, much of the gold is found in seams in the clay a few inches above bedrock. It is also found in the bedrock to a depth of 3 feet. The gold is said to occur irregularly on the creek. Some ground has been very good and has yielded from \$2 to \$4 a cubic yard. Much of the gold is coarse. A flat nugget found during the season of 1903 was 2 by 1½ inches in size and weighed 2½ ounces; some quartz was attached, and the nugget appeared to have been derived from a seam in the bedrock.

Eagle Creek is about 4 miles long. The valley widens sharply below the junction of the forks to one-fourth mile or more. Work has been done for about 2 miles below the junction. The depth to bedrock ranges from 14 to 18 feet. The bedrock and gravels are

similar to those on other creeks. There is about 6 feet of overburden, and gold, ranging from 50 cents to over \$2 a square foot of bedrock, has been found in about 6 feet of gravel over a width of 30 to 80 feet. Some of the gold is coarse, one piece worth \$74 having been found. The grade of the gold of Eagle Creek and Mastodon Fork is the highest found in the Birch Creek district.

HARRISON CREEK.

Brooks¹ describes Harrison Creek substantially as follows:

Gold was found on Squaw Gulch, a tributary of Harrison Creek, as early as 1894, and considerable work was done on the main stream up to 1896. As no high values were found, Harrison Creek was neglected for richer placers, and it is only within the last few years that the problem of working its relatively low-grade deposits has been seriously considered.

The creek has two forks, North and South, on both of which gold has been found, but only the former is now being developed. One of the first discoveries of gold in the basin was at Pitkas Bar, at the junction of the forks.

Only the upper part of North Fork was visited. The flat valley floor is 200 to 300 yards wide. There is a steep slope on the south side, but on the north the slope rises more gently and is deeply covered with talus. There are no excavations in this slope, and no topographic evidence of benches was noted, but it seems possible that benches may exist beneath the slide material. Farther downstream the valley gradually contracts and it is said to become a steep-walled canyon before it joins South Fork, whose valley is somewhat broader and appears to be more symmetrical. From the junction the valley continues to broaden until it merges with the Birch Creek valley 12 miles below.

The bedrock on North Fork is probably chiefly quartz-mica schist, but the occurrence of some pebbles of granite in the alluvium indicates the presence of that rock within the basin. Few bedrock exposures were seen, but the character of the alluvium indicates that the schists are cut by numerous quartz veins, many of which are stained with iron, indicating mineralization. A slab of schist cut by a gold-bearing quartz vein was found near the forks.²

Just above the canyon the depth to bedrock is said to be 20 feet. Six or seven miles above, near Discovery claim, the depth is 8 to 9 feet on the north side of the valley near the center and only 3 or 4 feet near the south wall. A mile or more still farther upstream the depth

¹ Bull. U. S. Geol. Survey No. 314, 1907, pp. 195-197.

² Spurr, J. E., *Geology of the Yukon gold district, Alaska: Eighteenth Ann. Rept. U. S. Geol. Survey*, pt. 3, 1898, pp. 353-354.

is 8 to 12 feet. In this part of the valley the grade of the stream and of the bedrock floor is probably about 75 to 100 feet to the mile. Although no accurate data are available, the reconnaissance maps indicate that about the same grade continues throughout the basin.

Well-rounded gravels characterize the alluvial deposits so far as seen. Boulders more than 2 feet in diameter are uncommon, though some measuring 3 feet were observed. Much the greater part of the material is schist, with some quartz and a little granite. The gravels are well stratified, are loose, and so far as known are not frozen. Their condition has prevented the creek from being thoroughly prospected, because the water flows in the gravel throughout the year.

Little turf or muck rests on the gravels, and the whole section is in most places made up largely of sand and gravel. Most of the bedrock is weathered and is broken by seams of clay, a secondary product, but so far as seen by the writer there is no well-defined stratum on the bedrock at the base of the gravels.

The gravels of both forks are known to be more or less auriferous. At a number of localities some gold has been mined by pick and shovel, but the tenor of the gravels, so far as determined, is too low to pay for working by this method. It is reported that as high as \$5 a day has been made on this creek. The gold appears to be rather evenly distributed both horizontally and vertically. There is, however, a marked concentration in the lower 3 to 5 feet of the gravels, and much of the weathered schist carries gold to a depth of 1 to 2 feet. The gold is fine, flaky, and bright-colored. The largest nugget reported, with a value of \$4, was found on the upper part of the creek. There has not been sufficient prospecting to determine the value of any considerable body of gravel; 5, 10, and 30 cent pans are reported from bedrock, but these of course can not be considered an average. Near the Discovery claim 13 pans taken from gravel near bedrock are said to have yielded about \$1 worth of gold. Considerable garnet and pyrite occur with the concentrates.

MINING DEVELOPMENT.

Mining in the Birch Creek district, on account of the comparative shallowness of the alluvial deposits, has been carried on almost entirely by open cuts and shoveling into sluice boxes. Modifications of this method have from time to time been introduced. Automatic dams, for example, are used on some of the creeks. The use of bottomless scrapers for removing the overburden and bringing the gravel to the boxes has been employed with success, notably on Mastodon Creek. Summer work can be carried on ordinarily from about the middle of May to the middle of September. A small amount of

ground is deep enough for drifting, and this method is employed to a small extent during the winter.

In 1903 the first power plants were used, and later, with the construction of ditches, the hydraulic method was introduced. (See Pl. XIII, B, p. 60.) This method has been found successful and, with modifications made necessary by the low grade of the creeks, is being rapidly extended wherever the conditions will permit. The process employed on Mammoth Creek is described by Ellsworth¹ as follows:

Mammoth Creek has a very low grade, and in order to overcome this difficulty a plant was installed which is novel in Alaska but is identical in principle to the one installed on Eagle Creek in 1908. The general plan of operation is as follows: First, a bedrock drain is excavated to dispose of the water in the cut and to carry away the overlying muck, which is hydraulicked off from the gravels to be handled by the first set-up. A channel is then groundaluced back of and above the cut and opposite the hydraulic giants. In this channel substantially constructed sluice boxes (with block riffles), similar in design to those ordinarily used in hydraulicking, are set up with a grade depending on the character of the gravels to be washed. A sheet-iron back stop about 10 feet high is then erected back of and against the boxes. The auriferous gravels are driven directly by the water from the nozzles of the giants against the back stop, from which they drop into the sluice boxes. A gravel incline is formed in front of the boxes by the stream of water as soon as operations are begun, and for this reason the force of the moving gravel is not expended against the sides of the boxes. The water for transporting and washing the gravel, after it is dropped into the boxes, is diverted from the creek about 1 mile above and carried in a ditch to the head of the sluice and after passing through is carried away in the bedrock drain. The tailings which accumulate at the end of the sluice are "piped" back out of the way by a separate giant set up at any convenient place. It is not ordinarily necessary to operate this giant continuously. The frequency with which the tailings have to be moved depends on the dumping room at the end of the boxes and the rate at which the gravel is being moved. This process does, however, require a quantity of water which should be taken into account in considering the supply necessary for such a system.

This method is especially adapted to working creek deposits with medium depths of gravel, where the slope of the bedrock is insufficient to permit the removal of the tailings by gravity. It has several advantages over elevators. The initial expense is less and the water required is less. No such heavy parts are required, which is an important item, especially in the more remote districts, where transportation is always expensive and often uncertain. The cost of set-ups is not as great and the chances of delay incident to repairs and replacement of parts are no greater than in ordinary hydraulicking.

¹ Ellsworth, C. E., Bull. U. S. Geol. Survey No. 442, 1910, p. 227.

WATER SUPPLY OF THE CIRCLE DISTRICT.

By C. E. ELLSWORTH and G. L. PARKER.

GAGING STATIONS AND MEASURING POINTS.

Gaging stations were maintained or discharge measurements made in 1910 in the Circle district at the following places:

Gaging stations and measuring points in Circle district, 1910.

• Birch Creek drainage basin:

Birch Creek below Clums Fork.
 Birch Creek at Fourteenmile House.
 Fryingpan Creek below forks.
 Great Unknown Creek near mouth.
 Clums Fork at mouth.
 McLean Creek at mouth.

North Fork of Birch Creek drainage basin:

North Fork of Birch Creek above Twelvemile Creek.
 Ptarmigan Creek at mouth.
 Golddust Creek $4\frac{1}{2}$ miles above mouth.
 Butte Creek at mouth.
 Bear Creek at mouth.
 Twelvemile Creek at mouth.
 East Fork of Twelvemile Creek at mouth.

Crooked Creek drainage basin:

Crooked Creek at Central House.
 Porcupine Creek above ditch.
 Porcupine Creek below Bonanza Creek.
 Bonanza Creek above ditch intake.
 Mammoth Creek at Miller House.
 Mammoth Creek ditch at intake.
 Independence Creek at mouth.
 Miller Creek at claim "No. 6 above."
 Miller Creek at mouth.
 Boulder Creek at trail crossing.
 Deadwood Creek above Switch Creek.

Preacher Creek drainage basin:

Preacher Creek above Bachelor Creek.
 Bachelor Creek below Costa Fork.
 Bachelor Creek at mouth.
 Costa Fork at mouth.

BIRCH CREEK DRAINAGE BASIN.

Birch Creek flows into Yukon River almost exactly on the Arctic Circle and about 25 miles directly west of Fort Yukon. Its mouth is about 5 miles west of the confluence of Chandalar River with the Yukon.

The drainage comes almost entirely from the south and west through a complex system of watercourses, and in outline the basin is extremely unsymmetrical. The headwaters interlock with those of Little Chena and Chatanika rivers and flow east for about 60 miles to the junction of the South Fork, where the stream makes an abrupt turn northward. About 12 miles beyond this point it leaves the mountainous country and enters the lowlands of the Yukon, through which it sluggishly flows in a meandering channel for over 100 miles, roughly paralleling the Yukon at a distance varying from 10 to 20 miles.

The principal tributaries are Clums Fork and South Fork from the south and east and North Fork and Harrison, Crooked, and Preacher creeks from the north and west. The headwaters of South Fork rise opposite those of Salcha and Charley rivers.

Monthly discharge of Birch Creek at Fourteenmile House for 1908 to 1910.

[Drainage area, 2,150 square miles.]

Month.	Discharge in second-feet.				Run-off (depth in inches on drainage area).
	Maximum.	Minimum.	Mean.	Mean per square mile.	
1908.					
June 26-30.....	1,190	1,020	1,090	0.507	0.09
July.....	2,630	847	1,140	.530	.61
August.....	1,620	825	1,080	.502	.58
September 1-29.....	6,070	900	2,150	1.00	1.08
The period, 96 days.....	6,070	825	1,423	1.48	2.36
1909.					
May 15-31.....	9,970	3,320	5,930	2.76	1.74
June.....	8,640	1,860	3,410	1.59	1.77
July.....	8,280	960	2,200	1.02	1.18
August.....	3,020	974	1,830	.851	.98
September.....	960	730	799	.372	.42
October 1-2.....	792	792	792	.368	.03
The period, 141 days.....	9,970	730	2,510	1.17	6.12
1910.					
May 13-31.....	6,620	3,200	4,790	2.23	1.58
June.....	6,000	1,160	2,500	1.16	1.29
July.....	5,460	551	1,430	.665	.77
August.....	1,880	432	950	.442	.51
September.....	3,280	1,040	1,620	.753	.84
October 1-6.....	1,140	1,080	1,090	.507	.11
The period, 147 days.....	6,620	432	2,010	.935	5.10

Monthly discharge, in second-feet, of Birch Creek and Fryingpan Creek for 1910.

Day.	Birch Creek below Clums Fork* (drainage area, 600 square miles).				Birch Creek at Fourteenmile House* (drainage area, 2,150 square miles).						Fryingpan Creek below the forks: (drainage area, 15.9 square miles).		
	June.	July.	Aug.	Sept.	May.	June.	July.	Aug.	Sept.	Oct.	June.	July.	Aug.
1.....		1,010	550	457		4,070	3,690	1,680	1,040	1,140		6.7	4.1
2.....		604	424	508		3,370	2,860	1,430	1,180	1,060		5.8	3.1
3.....		391	353	487		2,900	2,070	1,200	1,430	1,080		5.2	3.1
4.....		296	272	497		2,810	1,680	984	1,410	1,080		4.9	2.1
5.....		2,610	237	666		2,420	1,610	756	1,380	1,080		6.7	2.1
6.....		1,370	220	881		2,190	5,460	735	1,650	1,080		6.5	2.1
7.....		816	188	684		1,840	3,060	648	1,680			5.4	2.1
8.....		518	539	175	593	1,590	2,360	587	1,550		5.4	4.9	2.1
9.....		566	409	164	539	1,480	1,810	605	1,380		11.2	4.8	2.1
10.....		2,030	349	147	497	2,040	1,200	648	1,250		17.0	4.5	2.1
11.....		2,610	296	147	477	3,950	1,030	623	1,200		15.2	5.7	2.1
12.....		2,660	284	142	438	6,000	968	575	1,200		12.6	6.2	2.1
13.....		1,420	307	125	396	3,810	4,920	900	527	1,120		12.0	7.2
14.....		848	258	120	424	4,260	2,980	830	471	1,140		10.5	5.8
15.....		604	207	123	1,810	5,240	2,260	760	460	1,180		8.9	5.4
16.....		604	169	120	1,860	6,120	1,930	690	432	2,840		7.3	4.9
17.....		529	161	125	1,760	6,070	1,680	620	432	3,280		5.7	4.3
18.....		462	276	357	1,560	5,880	1,600	551	449	3,220		5.4	6.5
19.....		383	409	1,710	1,230	5,020	1,460	952	605	2,800		5.1	5.8
20.....		374	296	1,130	848	4,540	1,370	1,200	1,890	2,320		4.9	5.3
21.....		400	233	720	783	4,260	1,280	920	1,550	1,780		7.2	5.4
22.....		2,080	227	577	049	4,210	1,560	808	1,360	1,510		8.8	5.8
23.....		1,100	269	539	593	4,370	3,320	770	1,180	1,430		6.8	6.0
24.....		733	550	457	561	4,730	2,440	808	960	1,410		6.0	6.3
25.....		467	561	572	577	6,140	1,460	1,120	1,000	1,380		5.3	5.7
26.....		378	353	783	599	6,620	1,250	1,200	1,230	1,410		5.1	2.7
27.....		344	276	745	561	6,000	1,160	1,020	1,410	1,450		5.1	2.6
28.....		396	233	835	555	5,670	1,710	830	1,380	1,430		5.3	2.5
29.....		1,150	194	696	524	3,370	4,110	770	1,300	1,320		5.2	2.5
30.....		1,680	340	599	438	3,200	3,900	770	1,230	1,200		9.0	11.0
31.....			752	524		3,400		936	1,130				7.6
Mean.....		971	485	448	748	4,790	2,500	1,430	950	1,620	1,090	8.09	5.50
Mean per square mile.....		1.62	0.808	0.747	1.25	2.23	1.16	0.665	0.442	0.753	0.507	0.509	0.346
Run-off (depth in inches on drainage area).....		1.38	0.93	0.86	1.40	1.58	1.29	0.77	0.51	0.84	0.11	0.44	0.40

*The discharges of Birch Creek below Clums Fork are based on a well-defined rating curve below 700 second-feet. Above 700 second-feet the curve was extended by means of the area and velocity curves, and it is believed to represent the true relation of gage height to discharge up to 2,000 second-feet.

†The discharges of Birch Creek at Fourteenmile House are based on a rating curve well defined between 500 and 2,300 second-feet.

‡The discharges of Fryingpan Creek are based on a rating curve well defined between 2.5 and 5.5 second-feet.

Miscellaneous measurements in Birch Creek drainage basin in 1910.

Date.	Stream and locality.	Drainage area.	Discharge.	Discharge per square mile.
July 26.....	Great Unknown Creek near mouth.....	Sq. miles.	Sec.-ft.	Sec.-ft.
July 25.....	Clums Fork at mouth.....	41.2	16.7	6.47
Do.....	McLean Creek at mouth.....	15.4	3.0	2.2

NORTH FORK OF BIRCH CREEK DRAINAGE BASIN.

Eagle and Ptarmigan creeks, whose headwaters are opposite those of Crooked Creek, join to form North Fork of Birch Creek. Below the junction North Fork flows southwestward for about 7 miles to the mouth of Twelvemile Creek, whence it flows southward for about 8 miles and unites with Harrington Fork to form Birch Creek proper, which flows east to its confluence with South Fork, a distance of approximately 45 miles.

Named from the head, the main tributaries from the north are Fish, Bear, and Twelvemile creeks. From the south, in the same order, Golddust and Butte creeks are the only important streams.

Miscellaneous measurements in North Fork of Birch Creek drainage basin in 1910.

Date.	Stream and locality.	Drainage area.	Discharge.	Discharge per square mile.
		<i>Sq. miles.</i>	<i>Sec.-ft.</i>	<i>Sec.-ft.</i>
July 28.....	North Fork of Birch Creek above Twelvemile Creek.	87.1	55	0.63
Do.....	Ptarmigan Creek at mouth.....	19.0	15.0	.79
July 27.....	Golddust Creek 4½ miles above mouth.....	9.5	8.6	.90
July 28.....	Butte Creek at mouth.....	9.2	2.2	.24
Do.....	Bear Creek at mouth.....	12.4	6.7	.54
July 13.....	Twelvemile Creek at mouth.....	44.5	18.9	.42
July 28.....	do.....	44.5	14.6	.33
June 9.....	East Fork of Twelvemile Creek at mouth.....	22.9	60.0	2.62
July 13.....	do.....	22.9	7.4	.32
July 28.....	do.....	22.9	9.2	.40

CROOKED CREEK DRAINAGE BASIN.

Crooked Creek, which is formed by the junction of Mammoth and Porcupine creeks, meanders through a rather broad valley for about 30 miles and discharges its waters into Birch Creek about 10 miles above Fourteenmile House. Not far below Central House the valley loses its identity in the flats of Birch Creek.

Mastodon and Independence creeks unite to form Mammoth Creek, which receives Miller Creek from the west about 2 miles below this junction. The total length of the portion of the stream called Mammoth Creek is less than 4 miles.

Deadwood and Boulder creeks are tributaries from the south, below and above Central House, respectively. They follow parallel courses about 3 miles apart, with a length of about 18 miles.

Albert Creek, the principal tributary from the north, drains the southern slope of the Crazy Mountains.

72 GEOLOGIC RECONNAISSANCE OF THE CIRCLE QUADRANGLE.

Daily discharge, in second-feet, of Crooked, Porcupine, and Bonanza creeks for 1910.

Day.	Crooked Creek at Central House ^a (drainage area, 161 square miles).				Porcupine Creek ^b above ditch intake (drainage area, 17.8 square miles).		Porcupine Creek below Bonanza Creek ^c (drainage area, 39.9 square miles).					Bonanza Creek ^b above ditch intake (drainage area, 7.9 square miles).		
	May.	June.	July.	Aug.	July.	Aug.	May.	June.	July.	Aug.	Sept.	June.	July.	
1.....		139	348	173	15	23	.....	100	38	42	9.7	28	19	
2.....		173	173	91	12	17.7	.....	82	29	31	9.7	32	15	
3.....		225	112	74	10	11.4	.....	102	23	25	9.5	36	10	
4.....		234	74	61	9.2	11.4	.....	85	19.7	22	9.3	30	9	
5.....		126	112	50	14	8.8	.....	73	48	17.8	10.9	29	32	
6.....		139	192	45	11	7.1	.....	64	38	10.9	12.4	23	25	
7.....		112	112	32	5.0	6.7	.....	49	27	12.6	12.4	20	14	
8.....		102	74	29	5.0	6.7	.....	43	23	11.6	11.8	20	12	
9.....		91	68	.....	3.7	5.4	.....	68	24	10.9	11.6	24	13	
10.....		300	61	.....	5.0	5.0	.....	131	19.9	10.5	11.3	42	10	
11.....		255	56	.....	4.5	4.5	.....	92	18.1	10.5	11.3	35	9	
12.....		212	50	.....	3.7	4.0	.....	77	17.2	9.7	11.3	30	8	
13.....		173	45	.....	3.7	4.0	.....	60	17.0	9.7	10.9	21	8	
14.....		139	40	.....	4.0	3.7	.....	46	15.6	9.3	11.3	16	7	
15.....		173	112	36	4.0	3.7	.....	44	10.9	9.0	38	15	5	
16.....		173	102	33	2.9	3.7	.....	55	10.1	9.3	40	19	5	
17.....		112	112	30	3.0	3.2	.....	46	10.5	9.3	32	16	5	
18.....		102	102	255	30	3.7	.....	36	71	9.5	26	12	30	
19.....		91	82	173	27	.....	.....	41	40	9.3	22	14	19	
20.....		112	74	126	17.7	.....	.....	57	28	9.9	17.6	19	13	
21.....		126	112	102	12.8	.....	.....	174	24	9.8	.....	28	11	
22.....		139	348	112	10.1	.....	.....	134	22	9.8	.....	30	10	
23.....		112	255	126	9.2	.....	.....	62	22	9.7	.....	27	11	
24.....		139	173	112	11.9	.....	.....	49	39	9.7	.....	24	16	
25.....		212	112	91	11.4	.....	.....	36	25	9.7	.....	15	12	
26.....		112	91	74	9.6	.....	.....	36	20	10.3	.....	18	9	
27.....		74	91	61	8.4	.....	.....	43	18.5	10.7	.....	18	8	
28.....		50	173	50	7.1	.....	.....	46	12.9	10.5	.....	20	8	
29.....		173	397	40	7.1	.....	.....	51	76	16.2	10.1	35	8	
30.....		234	448	32	62	.....	.....	73	60	173	9.9	30	27	
31.....		300	.....	212	41	.....	.....	127	74	9.7	.....	.....	30	
Mean.....		143	173	103	69.4	12.3	7.43	83.7	68.9	31.1	12.9	16.4	24.5	13.5
Mean per square mile	0.888	1.07	0.640	0.431	0.691	0.417	2.10	1.73	0.779	0.323	0.411	3.10	1.71	
Run-off (depth in inches on drainage area).....	0.56	1.19	0.74	0.13	0.80	0.25	0.23	1.93	0.90	0.37	0.32	3.46	1.97	

^a Discharges of Crooked Creek at Central House are based on a rating curve well defined between 30 and 350 second-feet.^b The discharges of Porcupine and Bonanza creeks above ditch intakes are only approximate on account of shifting channel conditions.^c The discharges of Porcupine Creek below Bonanza Creek are based on a rating curve fairly well defined between 10 and 60 second-feet.

Daily discharge, in second-feet, of Mammoth and Deadwood creeks for 1910.

Day.	Mammoth Creek at Miller House ^a (drainage area, 37.1 square miles).			Deadwood Creek above Switch Creek ^b (drainage area, 21.3 square miles).				
	May.	June.	July.	May.	June.	July.	Aug.	Sept.
1.....		80	47		58	68	15.3	5.0
2.....		95	25		58	25	11.0	5.5
3.....		77	21		55	15.3	8.7	5.0
4.....		66	30		39	13.2	7.7	5.0
5.....		66	90		35	18.2	6.4	5.8
6.....		62	54		27	13.2	6.4	6.4
7.....		54	33		27	11.0	5.8	5.0
8.....		54	25		16.4	11.0	5.6	5.0
9.....		63	17.5		39	7.7	5.0	5.0
10.....		79	17.5		35	6.4	5.0	5.0
11.....		64	17.5		41	6.4	5.0	5.2
12.....		63	17.5		31	5.8	4.5	5.5
13.....		58	17.5		27	5.0	4.5	6.4
14.....		49	21		21	5.0	4.3	7.7
15.....		48	17.5		21	5.0	3.8	25
16.....		53	14.8		21	4.5	3.8	18.2
17.....	30	51	19.0		21	5.4	3.8	18.2
18.....	47	30	11.8		15.3	50	5.0	15.3
19.....	47	32	49		15.3	25	5.5	13.2
20.....	35	49	37		18.2	13.2	6.4	11.0
21.....	25	91	36		21	13.2	5.7	
22.....	17.5	77	25		25	13.2	5.0	
23.....	54	61	25		21	8.7	4.5	
24.....	70	33	35		15.3	8.4	3.8	
25.....	47	25	25		13.2	7.2	5.5	
26.....	45	53	21		11.0	6.4	5.0	
27.....	44	67	17.5		11.0	5.5	6.4	
28.....	41	47	16.4		98	5.5	5.0	
29.....	65	115	14.8		102	9.4	5.8	
30.....	78	47	48	66	44	27	5.5	
31.....	93		38	77		19.9	5.0	
Mean.....	49.2	60.3	32.0	71.5	32.8	14.2	5.84	8.92
Mean per square mile.....	1.33	1.63	0.863	0.336	1.54	0.667	0.274	0.414
Run-off (depth in inches on drainage area).....	0.74	1.82	0.99	0.25	1.72	0.77	0.32	0.31

^a The discharges of Mammoth Creek below Miller House are obtained by adding to the discharge of the creek the amount of water diverted by the Mammoth Creek mining ditch. They are only approximate for certain periods during low water on account of insufficient data regarding the flow of the ditch.

^b The discharges of Deadwood Creek above Switch Creek are based on a well-defined curve throughout.

Daily discharge, in second-feet, of Bonanza Creek ditch at intake for 1910.

Day.	May.	June. ^a	July. ^a	Aug.	Day.	May.	June. ^a	July. ^a	Aug.
1.....		18.9	19.0	17.6	21.....		18.9	10.5	
2.....		19.2	13.0	13.1	22.....		0	10.2	
3.....		21	9.6	10.2	23.....		0	10.5	
4.....		23	8.4	8.4	24.....		24	15.7	
5.....		23	28	6.9	25.....		14.4	11.9	
6.....		20	20		26.....		15.7	8.7	
7.....		17.3	13.3		27.....		17.3	8.0	
8.....		16.0	11.5		28.....	14.7	16.9	0	
9.....		20	12.4		29.....	14.4	26	0	
10.....		22	9.4		30.....	13.2	28	26	0
11.....		23	8.4		31.....	15.0	27		
12.....		23	7.7						
13.....		20	7.7		Mean.....	14.3	17	11.6	11.2
14.....		16.0	6.6						
15.....		14.2	0						
16.....		18.6	0						
17.....		15.4	0						
18.....		12.1	27						
19.....		13.8	17.6						
20.....		18.9	12.2						

^a A change in the relation of gage height to discharge occurred during the period June 6 to July 15. Discharges for this interval were derived by the indirect method for shifting channels.

Miscellaneous measurements in Crooked Creek drainage basin in 1910.

Date.	Stream and locality.	Drainage area.	Discharge.	Discharge per square mile.
		<i>Sq. miles.</i>	<i>Sec.-ft.</i>	<i>Sec.-ft.</i>
May 29.....	Mammoth Creek ditch at intake.....		33	
June 5.....	do.....		24	
July 14.....	Independence Creek at mouth.....	13.2	4.6	0.35
July 23.....	do.....	13.2	6.8	.52
May 29.....	Miller Creek at claim "No. 6 above".....	7.2	11.1	1.54
June 5.....	do.....	7.2	17.4	2.42
July 14.....	do.....	7.2	3	.42
Do.....	Miller Creek at mouth.....	10.5	3	.29
July 23.....	do.....	10.5	6	.57
July 21.....	Boulder Creek at trail crossing.....	38.8	25	.64

CREEKS TRIBUTARY TO THE YUKON.**GENERAL FEATURES.**

The creeks tributary to the Yukon from the south above Circle within the Circle quadrangle are Woodchopper, Coal, and Washington. Fourth of July Creek heads within the quadrangle, but most of its valley is east of the eastern boundary. Its description is included, however, as it completes that of the area where work is in progress along the Yukon.

The belt of country drained by these creeks is 10 to 25 miles wide from east to west and is characterized by broad, undulating, more or less even-topped ridges rising about 2,000 feet above sea level. The valleys of the streams are deeply cut and comparatively narrow.

The bedrock includes the Birch Creek schist; several shales, cherty limestones, and igneous volcanic rocks belonging in part at least to the Devonian and Carboniferous; Lower Cretaceous slate and sandstone; and Tertiary conglomerate, sandstone, and shale; these are overlain by Quaternary silt, sand, and gravel. Granitic intrusive rocks are present round the heads of Coal and Woodchopper creeks.

The gold is believed to have been derived in part from Lower Cretaceous slates, in part from Tertiary conglomerate, and in part from the Birch Creek schist.

PLACERS.**WOODCHOPPER CREEK.**

Woodchopper Creek was visited in 1906 by Brooks,¹ from whose description the following is quoted:

Woodchopper Creek, which is about 12 miles long, enters the Yukon from the west, about 30 miles above Circle. Its flood plain is about half a mile in width, and the alluvium is probably 8 to 15 feet deep. Five miles from the Yukon, Mineral Creek, the scene of some placer mining, joins Woodchopper Creek from the south.

¹ Brooks, A. H., Bull. U. S. Geol. Survey No. 314, 1907, pp. 203-204.

The floor of the Mineral Creek valley is 100 to 150 [feet] wide, and the slopes are broken by benches. Woodchopper Creek has a gradient of about 100 feet to the mile. Remnants of benches are to be seen along the creek, the highest of these being marked by the ridge on the northwest side, which is flat and slopes toward the Yukon.

In the lower mile of Woodchopper Creek only massive greenstones were observed. Above these is a belt of black slate and limestones about a mile wide that continues nearly to the mouth of Mineral Creek, where it is succeeded by friable conglomerates in a belt said to be several miles wide. Chert and quartz pebbles dominate in the conglomerate, which is only imperfectly consolidated and outcrops in few places. This fact often leads to its being mistaken for bench gravel by the prospector.

So far as known the gold-bearing alluvium is confined to those creeks that cut the conglomerate, which, therefore, appears to be the source of the gold. Mineral Creek and its tributary, Alice Gulch, are the only streams which have thus far been found to be productive. Prospects are reported from Grouse and Iron creeks.

At the mouth of Mineral Creek the alluvial floor of the valley is about 75 yards wide but narrows upstream. A mile upstream, at the mouth of Alice Gulch, it broadens out again into a basin about 75 yards wide. On the south wall of Mineral Gulch three well-defined benches were observed, having altitudes of about 20, 150, and 250 feet above the creek.

Muck is encountered on some claims to a depth of 30 feet; the gravels underneath vary in thickness from 2 to 5 feet and are made up chiefly of well-rounded quartz and chert pebbles. The pay streak lies in parallel channels 12 to 14 feet wide, as many as three of these channels having been found in a width of 80 feet. The pay streak under present systems of mining is from $1\frac{1}{2}$ to 4 feet in thickness. A varying amount of bedrock is taken up, depending on its looseness. Apparently gold occurs in bedrock beyond the depth to which it can be profitably extracted. The bedrock appears to be chiefly conglomerate, but in some places a plastic clay, which may be a weathered shale interbedded with the conglomerate, has been encountered. Prospectors report that the values are found in the conglomerate but appear to be absent in the clay. The conglomerate bedrock is invariably iron stained, where found under the placers. Gold has been found in the lower benches of the creek, but the higher benches have not been prospected.

The gold in the creek bed is usually bright colored, but that of the benches is dark. Most of the gold is coarse, the largest nugget having a value of \$30. The value of the gold as reported by the miners is \$19.09 to \$19.30 per ounce, which would make it the highest of all found in the Yukon province. Values of 5 to 50 cents to the pan on bedrock are reported, but there are no data available for the average tenor of the pay streak.

In 1911 gold had also been found in the valley of Woodchopper Creek, about a mile above the mouth of Mineral Creek. The valley at this point has a flat half a mile or more wide on the west side of the creek, and in this flat several hundred feet from the stream gold had been discovered. The bedrock is conglomerate. The depth to bedrock is about 22 feet and the thickness of gravel about 11 feet. A large proportion of the bottom gravels consists of granite boulders from the head of the creek. Gold is reported to be present in the lowermost 6 feet of gravel over a width of about 70 feet. Good returns were reported.

COAL CREEK

Mining was reported to be about as active in the lower part of the Coal Creek valley during 1911 as it was on Woodchopper Creek.

The most noteworthy discovery of the year was at a point about 15 miles from the mouth of Coal Creek, where gold was found in but near the southern limit of an area of Paleozoic rocks. The bedrock includes chert, shale, greenstone, and limestone. The depth to bedrock at the place where work was being done is about 7 feet and the productive gravels are reported to be 100 feet wide. The proportion of garnets in the gravels is large. Fragments and boulders of garnetiferous schist are also common and the facts suggest that the placer gold has been derived from the Birch Creek schist, which outcrops around the head of Coal Creek.

WASHINGTON CREEK

Brooks¹ visited Washington Creek in 1906. He describes conditions as follows:

Gold.—Washington Creek flows through a northward-trending valley, whose floor is from half a mile to a mile in width. The bedrock for the lower 3 miles of the creek is black slate or shale of Cretaceous age.² Farther upstream the creek cuts a greenstone and chert formation, probably of Devonian age, and 10 miles from the Yukon it crosses another belt of Cretaceous slate, which forms the bedrock in Nugget Gulch, a small southerly tributary. These rocks are succeeded to the south by a broad belt made up of a Tertiary conglomerate, sandstone, and shale series, which contains some lignitic coal seams. This belt of coal-bearing rocks has a width of at least 10 miles. Still higher up the valley older rocks are said to occur again.

Placer gold has been found at two localities in the Washington Creek basin—(1) in Nugget Gulch, about 9 miles from the Yukon, and (2) on Surprise and Eagle creeks, about 10 miles above. The placers on Nugget Creek consist of very much localized accumulations of coarse gold on bedrock. Values are so irregularly distributed that it is questionable whether they can be mined at a profit. The gold appears to have its source in the Cretaceous slates, and it is worthy of consideration at least whether the mineralization of the bedrock is not sufficiently localized to pay the cost of extraction. The upper locality was not visited by the writer, but from the best accounts the gold here appears to be derived from a conglomerate. The value of the total production of Washington Creek does not exceed a few thousand dollars.

Coal.—Washington Creek has been the scene of some ill-advised attempts at coal mining. Though there is considerable lignite in the basin, much of the money spent in development has been wasted on experiments in transportation rather than in testing the seams as to extent and quality. The coal openings are from 10 to 14 miles up the creek, and as the seams exposed appear to be of no better quality or greater thickness than others which lie much closer to the Yukon, the outlook for profitable exploitation is not hopeful. The seam examined by the writer, about 14 miles from the river, occurs in friable sandstone and shale, striking about east and west and dipping 30° N., and showed the following section. The exposure is on the north side of the valley, about 40 feet above the stream level.

¹ Brooks, A. H., Bull. U. S. Geol. Survey No. 314, 1907, pp. 200-202.

² Collier, A. J., Coal resources of the Yukon: Bull. U. S. Geol. Survey No. 218, 1903, pp. 23-32.

Section of coal seam on Washington Creek.

	Ft. in.
Roof, soft blue-gray shale.	
Shaly lignitic coal	2 6
Clay	2
Shaly lignitic coal	2
Bone parting	2
Good lignitic coal	1
Clay	5
Good lignite	1
Clay shale	1
Impure coal (lignite)	3
Clay shale	2
Coal (lignite)	1 4
Clay shale	2
Lignitic coal with some partings	2
Clay shale	3
Impure lignitic coal	1
Good coal (lignite)	1
Clay shale	4
Good lignitic coal with bone partings	1 4
Clay shale with some bone partings	4
Covered, but probably no coal.	

The coal carries considerable sulphur. On burning it produces many clinkers. The ash has a reddish tinge. The following is an analysis of a sample taken from this same district a little lower down the creek:

Analysis of coal from Washington Creek.¹

Water	13. 48
Volatile combustible matter	43. 74
Fixed carbon	39. 68
Ash	3. 10
	100. 00
Sulphur	. 24

The remarkably low percentage of ash suggests that this sample was taken from one of the minor seams and was not an average of the entire section exposed. Such a grade of coal could probably only be secured by hand picking after mining.

During 1905 and 1906 a company attempted to establish a winter transportation system to the Yukon by the use of a 100-horsepower traction engine, which was expected to haul five sleds, each of 10 tons capacity. While such a scheme might be feasible with a good roadbed, it proved entirely impracticable without one. This plan involves the storage of the coal hauled in winter for consumption during the summer months—a doubtful experiment, because the lignite slacks readily after being exposed to the air.

In spite of the adverse conditions of mining and low grade of coals in this field, it shares with other fields of the Yukon a prospective value. There can be no question that, with the present increase in the demand for fuel and the rapid destruction of the forests, the time is not far distant when the Yukon lignites will play an important part in the commercial development of the inland placer districts.

FOURTH OF JULY CREEK.

Fourth of July Creek rises about 12 miles from the Yukon and flows northeastward for the greater part of its course. Crowley Creek, its largest tributary, enters it from the east about 6 miles below its head.

¹ Collier, A. J., Coal resources of the Yukon: Bull. U. S. Geol. Survey No. 218, 1903, p. 31.

Four miles farther downstream Fourth of July Creek leaves its valley, crosses the flat of the Yukon in a northwesterly course, and about 2 miles beyond is reported to enter a slough on the Yukon about 2 miles below Nation, which is situated on the south bank of the Yukon about 4 miles below the mouth of Nation River. Michigan Creek, a neighboring stream on the east, leaves its valley at about the same distance from the Yukon as Fourth of July and is reported to enter the same slough about a quarter of a mile farther up the river.

The main part of the valley of Fourth of July Creek is about 2,000 feet below the level of the ridges and has a comparatively narrow stream flat from 200 to 400 feet in width. Above the mouth of Crowley Creek the valley has a steep eastern slope, close to which the stream flows, and a gentle benchlike western slope about 1,000 feet wide that merges with the base of the ridge. Below the mouth of Crowley Creek it is mostly narrower, till it nears the valley of the Yukon, where its floor widens and merges with that of the river. At this point it has a benchlike slope on the east half a mile or more in width. The grade of the creek is about 100 feet to the mile. The drainage area being comparatively small and the precipitation for the general area being low, averaging hardly more than 10 inches a year, the quantity of water is generally insufficient for mining. The timber resources are limited to a comparatively light growth of small spruce and a little birch and poplar. Some larger spruce timber is available in the valley of the Yukon.

The bedrock of Fourth of July Valley from the mouth to Crowley Creek is predominantly limestone, which at the point where the creek enters the Yukon Valley forms picturesquely weathered cliffs towering above the stream on its west side. Upper Carboniferous fossils are abundant in similar limestone near the mouth of Michigan Creek, and the limestones at both these localities are considered to be of the same age and are correlated with the upper Carboniferous limestones on the north side of the Yukon above Nation River, described by Brooks.¹ The limestones occur as massive beds that have been so folded as to be vertical at some localities; where cut by Yukon River they are conspicuous as open folds.

The bedrock from Crowley Creek to the head of Fourth of July Creek and around all the headwaters, so far as observed, is conglomerate continuous with the conglomerate of the Seventymile district, the age of which has been determined as Tertiary. Along Seventymile River these rocks have been closely folded and in many places are nearly vertical. Their structure on the ridges is for the most part obscured by the gravel into which they have weathered. It

¹ Brooks, A. H., and Kindle, E. M., Paleozoic and associated rocks of the upper Yukon, Alaska: Bull. Geol. Soc. America, vol. 19, 1908, pp. 295-297.

has been rather definitely determined that the gold of the placers has been derived from this conglomerate, for the only portions of the Fourth of July Valley and its tributaries where gold has been mined are those areas where the conglomerate is the bedrock and where the streams have had no access to any other bedrock.

Fourth of July Creek is reported to have produced altogether about \$50,000. Most of the work on the main creek has been confined to about six claims. The depth to bedrock averages about 9 feet and the thickness of gravel mined 5 to 6 feet. Most of the gravel is comparatively fine, with pebbles reaching about 6 inches as a maximum, but a few boulders of quartzite and hard Paleozoic conglomerate 3 feet or more in diameter were observed. All the pebbles and boulders observed were well worn, and there is little doubt that all have been derived from the Eocene conglomerate.

The gold is mostly close to bedrock, the greatest proportion of it being found in the lowest foot of gravel. The width over which it is found had not been determined. Most of it is flat and in rather thick flakes, as much as one-fourth inch in diameter. It is reported to range in assay value from \$18.89 to \$18.91 per ounce. Returns ranging from \$8 to \$75 a box length (144 square feet), with an average of about \$25, are reported.

The most noteworthy feature of mining operations during 1911 was the introduction of mechanical means for working the gravels on a larger scale. A steam scraper, with 86 horsepower available, was put into operation during the first week in September, 1911, and was intended to be used extensively during the summer of 1912. It was transported during the summer from the Yukon under its own power for a distance of about 10 miles over the brushy valley at an average speed of about half a mile a day. The method used was to dig holes at regular intervals in the frozen ground, insert a large hook for a deadman and then pull the scraper forward on its foundation of logs by cables attached to the drum.

Open-cut work was being done in 1912 on Ruby Creek, which enters Fourth of July Creek about 3 miles above the point where the scraper was in use. The only bedrock in this valley, so far as observed, is the conglomerate. The depth to bedrock at places where mining was in progress is 12 to 15 feet. The gravel is made up of material derived from the conglomerate, and the gold is found in the lower 20 inches. Returns are reported ranging from \$50 to \$75 to the box length of 144 square feet.

MISCELLANEOUS AREAS.

SEVENTYMILE REGION.

Placer mining in the upper Seventymile region has been in progress on Flume Creek near the mouth and on Alder Creek. The ground on both these creeks is shallow. Several nuggets ranging from \$1 to \$19 in value have been reported from Alder Creek.

FORTYMILE REGION.

Gold Run, a tributary of Slate Creek, about 75 miles southwest of Eagle, has been mined more or less for several years. The bed-rock is a rather coarse schistose sandy quartzite regarded as Paleozoic. The area is close to the large granitic mass to the north and west and the gravels contain abundant quartz. The gravels are shallow and are worked by open cut and automatic dam. They were being mined in 1904 and two men were working on them in 1911.

A small amount of mining has been done on Hutchinson Creek and its tributaries, Coldfoot and Montana creeks, for several years; five men were reported to be working there in 1910. There has been a small production from this area.

Some work has been done on the quartz prospects on Mosquito Fork. (See p. 49.)

SALCHA REGION.

The first mining in the Salcha region was done in 1905, Butte and Caribou being among the creeks then prospected. The bed-rock of the region is mostly Birch Creek schist. The thickness of deposits that were at that time being worked ranged from about 20 to 36 feet. The gravels consisted principally of schist, with some granite, vein quartz, and greenstone. The main difficulty encountered was thawed ground.

Work has continued in the region and in 1910 good results were reported from No Grub and Caribou creeks, where about 20 men were employed on about five claims.

CHENA REGION.

Chena River and tributaries have been under investigation by prospectors since 1905. Gold has been found on a few creeks, but no results of importance have been reported.

FUTURE PROSPECTING.

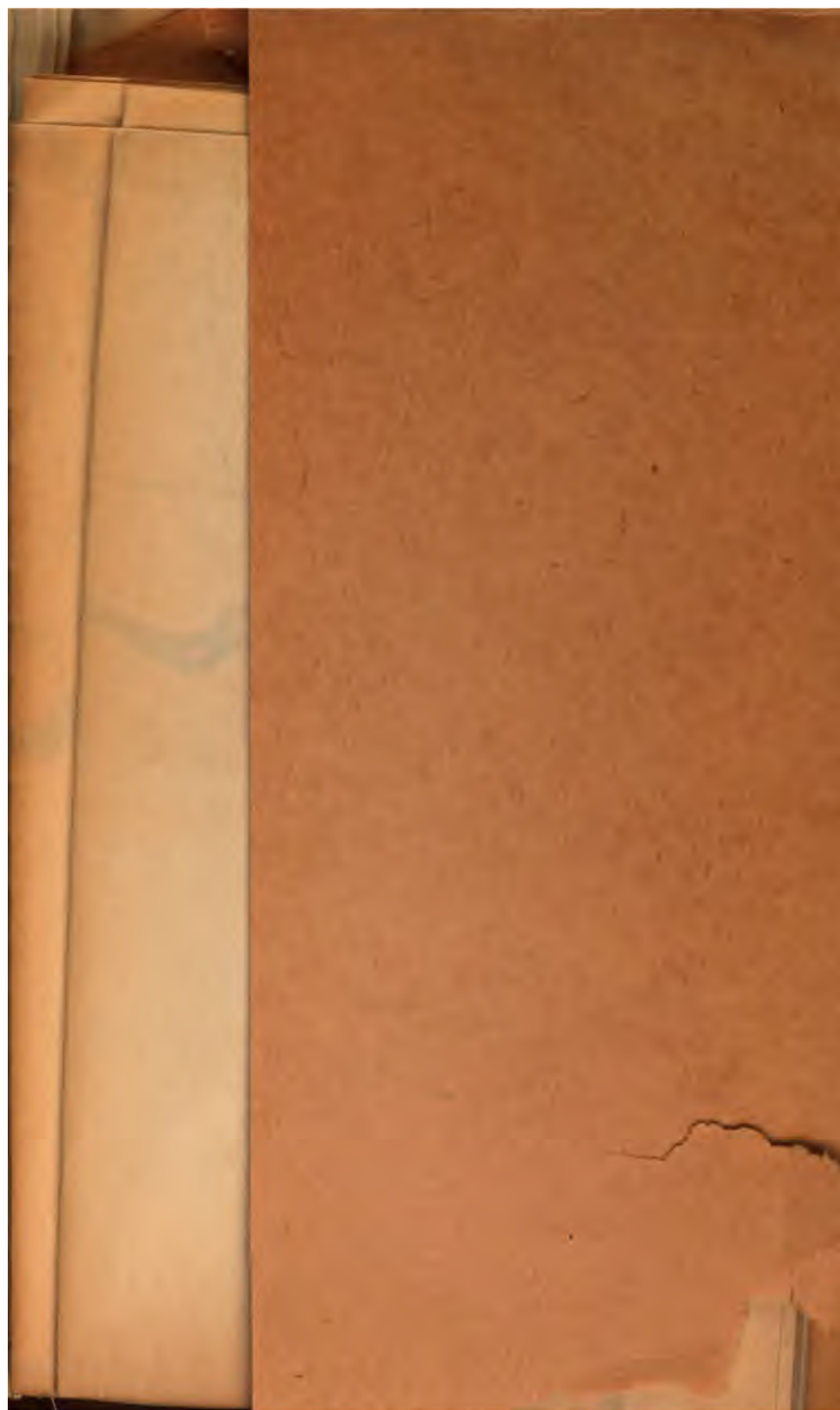
The chief importance of these miscellaneous occurrences just described lies in the fact that they illustrate the widespread distribution of mineralization. It seems probable that when conditions for the transportation of supplies to remote portions of the quadrangle become more favorable remunerative results will be possible in some of these areas. Such widespread distribution of mineralization, furthermore, is an incentive to further work in prospecting, particularly in the schistose rocks in the vicinity of the granitic intrusives.

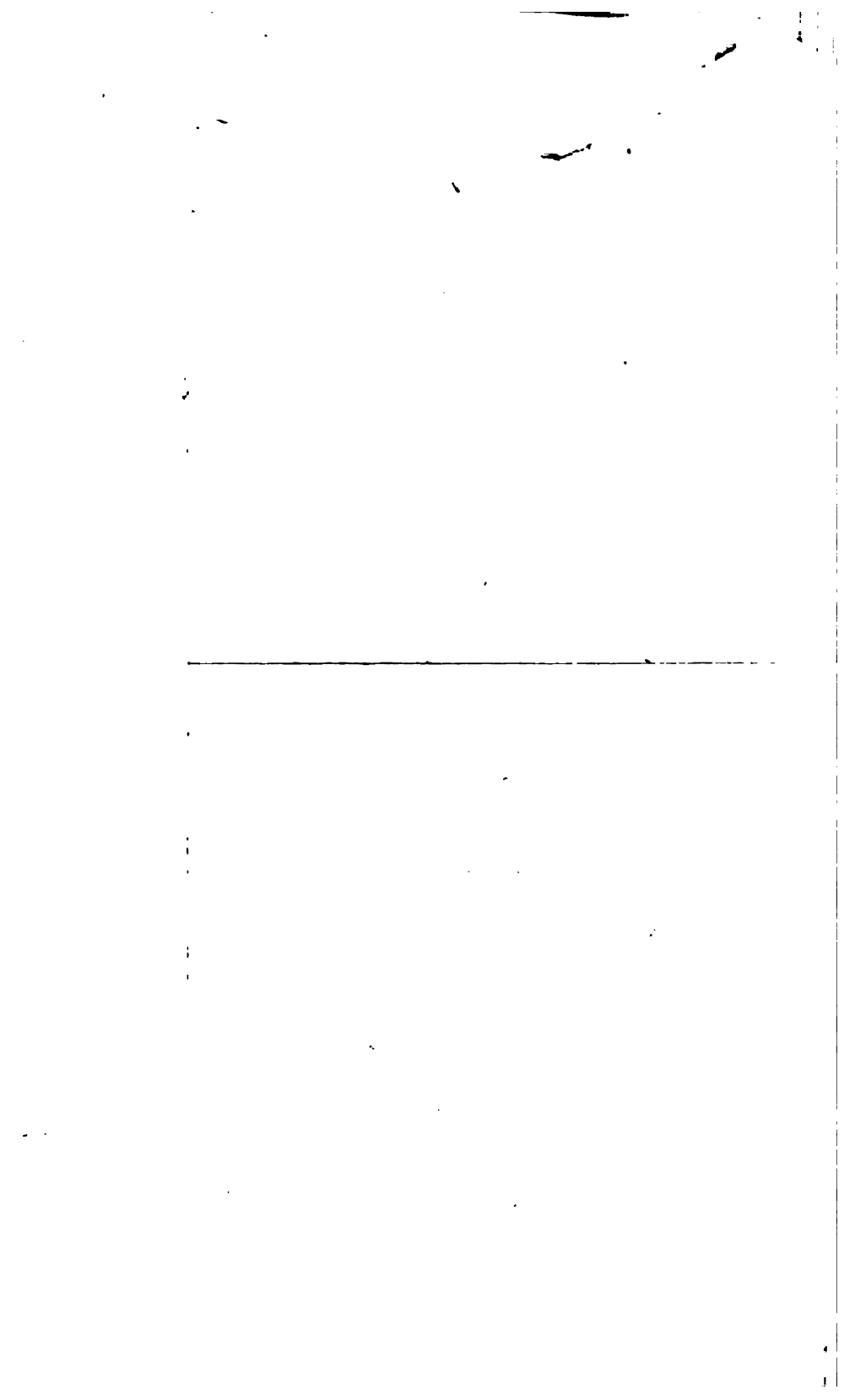
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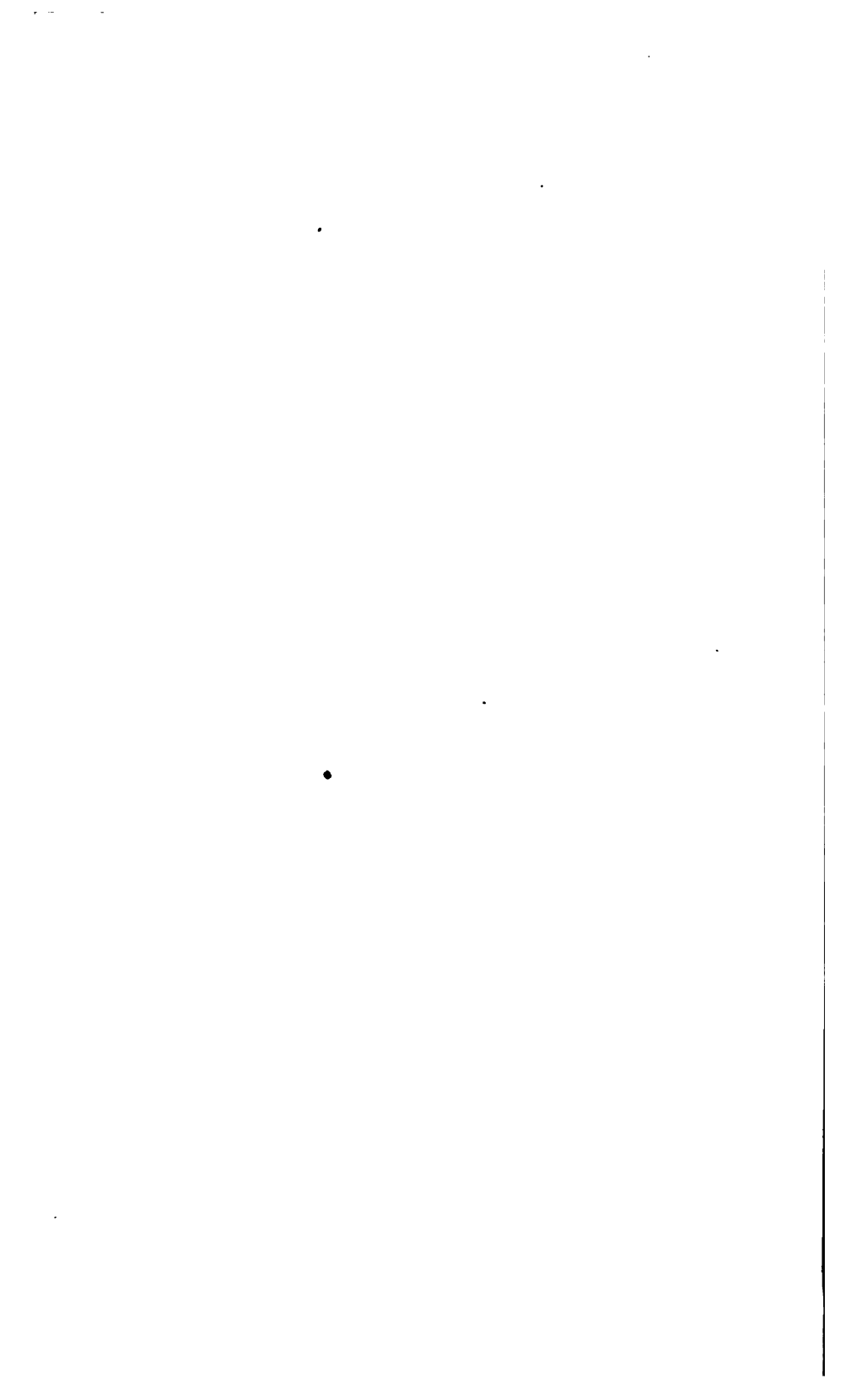
SOME ORE DEPOSITS IN NORTHWESTERN
CUSTER COUNTY, IDAHO

BY

JOSEPH B. UMPLEBY



WASHINGTON
GOVERNMENT PRINTING OFFICE
1913



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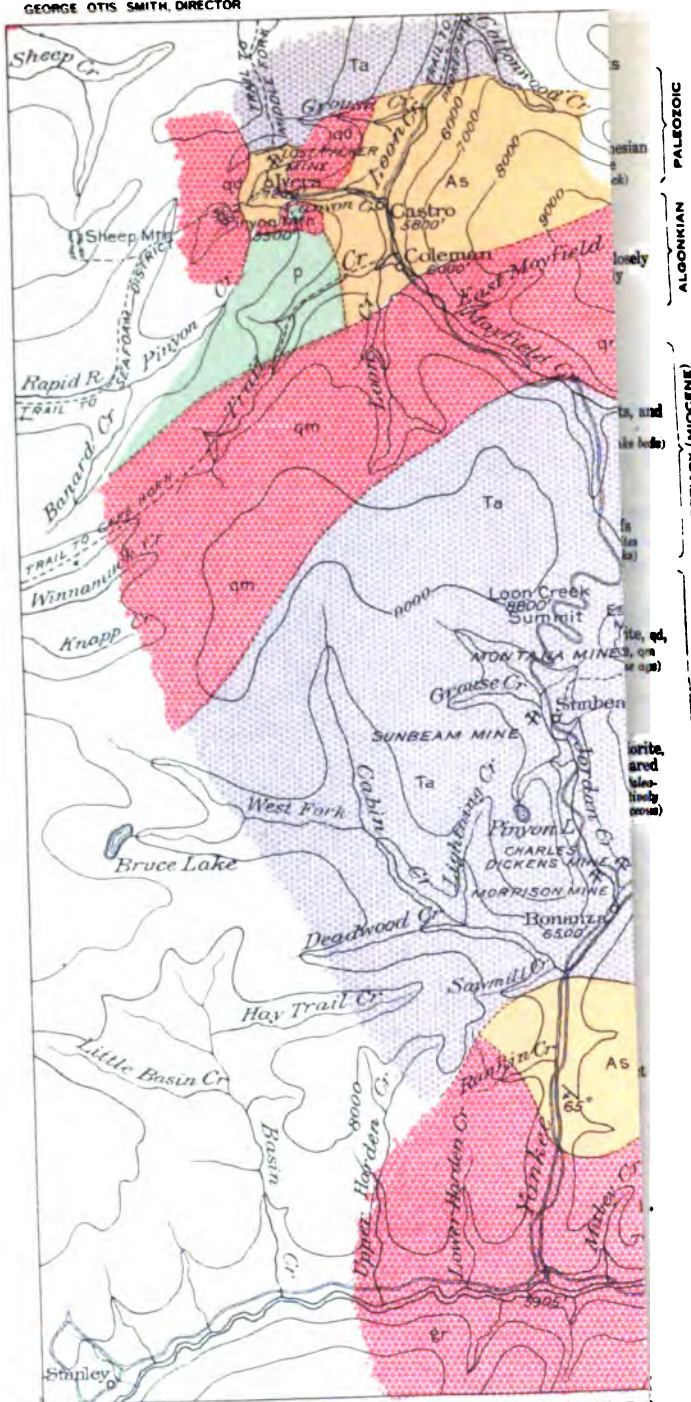
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TOPOGRAPHIC AND GEOLOGICAL

SOME ORE DEPOSITS IN NORTHWESTERN CUSTER COUNTY, IDAHO.

By **JOSEPH B. UMPLEBY.**

INTRODUCTION.

SCOPE OF THE REPORT.

This report sets forth the results of a short reconnaissance in the Loon Creek, Yankee Fork, and Bay Horse mining districts, situated in the northwestern part of Custer County, Idaho. The area includes several promising ore deposits and a few mines where a considerable tonnage is blocked out, awaiting more advantageous transportation facilities.

The area is first treated as a unit in order to bring out the broader relations, and then the three districts are taken up separately. Although this arrangement involves some repetition, it is thought to be justified in order that the report may be equally valuable to the student of the general subject and to the person interested in a particular district.

FIELD WORK AND ACKNOWLEDGMENTS.

Early in the fall of 1910 three days were spent in examining the Bay Horse district, it being the plan at that time to incorporate notes on the deposits there found in a report on Lemhi County. Later it was decided to make a reconnaissance of two other districts adjacent to Bay Horse and incorporate the results of the work in the three areas in a separate bulletin. Pursuant to this plan field work was begun August 27, 1911, and continued until September 20 of that year. The time was divided about equally between the Loon Creek, Yankee Fork, and Bay Horse districts. A topographic and geologic sketch map was prepared showing most of the area (2,500 square miles) included in these districts. (See Pl. I.) On this map only the broader geologic divisions are recognized and except along the main line of traffic from Challis to Ivers and over small areas adjacent to the more important metalliferous deposits, the positions assigned to their contacts are based largely on information derived from mining men and prospectors.

The base map is compiled from S. M. Ballard's map of Custer County, data furnished by the local office of the Forest Service, and

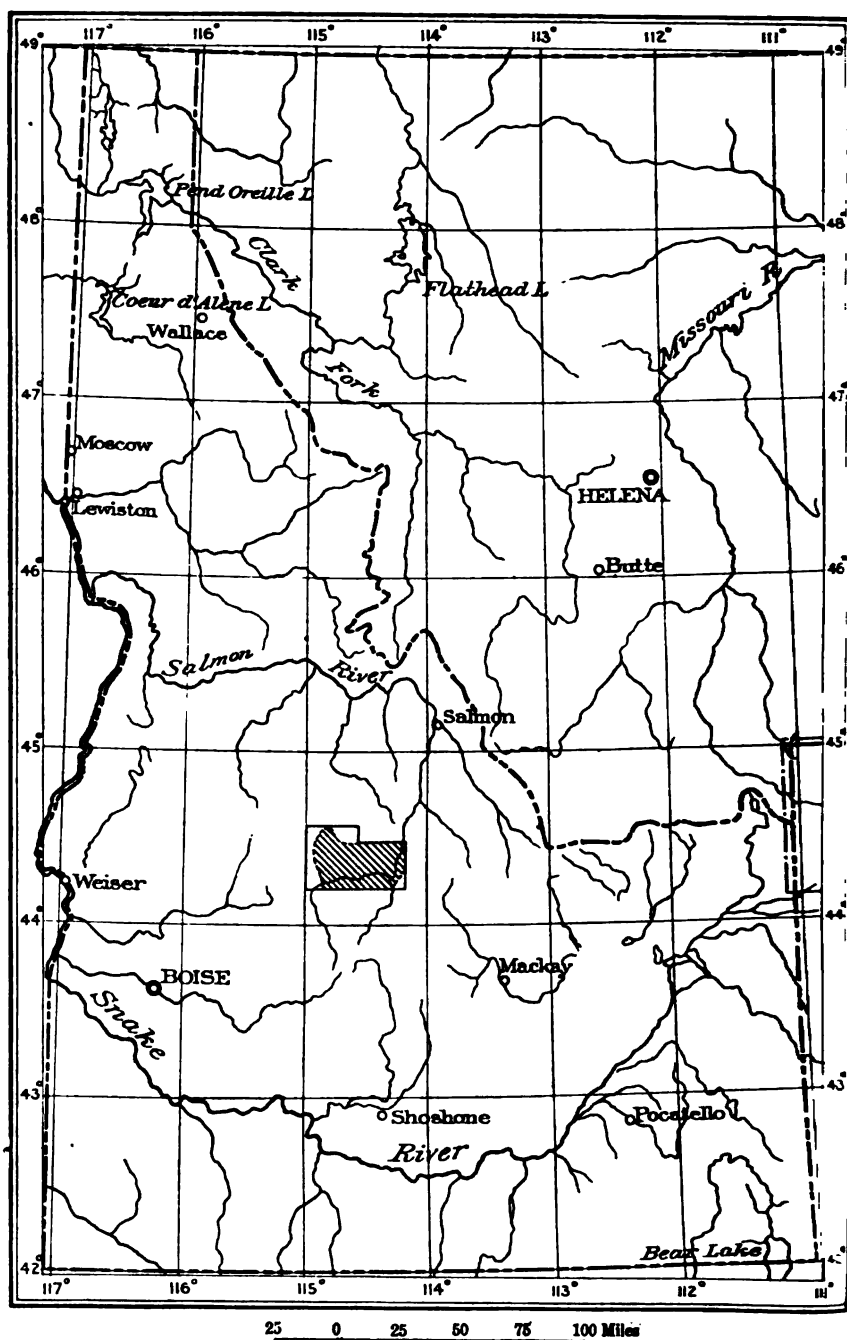


FIGURE 1.—Index map of Idaho showing location of area investigated.

numerous compass triangulations by the writer. Vertical control along Salmon River is taken from a location survey by the Gilmore & Pittsburgh Railroad; elsewhere it is taken from aneroid readings.

Field work was greatly facilitated by generous courtesies and assistance given by mining men in the area, especially by the officials of the Lost Packer Mining Co.

EARLIER WORK AND LITERATURE.

The earlier work in the area is described principally in short articles. George H. Eldridge, during his reconnaissance from Boise to Salmon, passed through a part of the Loon Creek district and on his return touched the northeast corner of the Bay Horse district. His report, however, contains little specific information concerning the area here considered. The Bay Horse district is the subject of a few notes by R. N. Bell, in which he describes the geologic features of the region and the occurrence of silver ores. In another paper the same writer incorporates notes on the mines of the Yankee Fork and Bay Horse districts. The Lost Packer mine is described briefly by E. P. Jennings. The annual reports of the State Mine Inspector, many of which contain notes on the geology of the deposits, form another source of information regarding the ore deposits of the area. The more important reports and articles on this and nearby areas are listed below in chronologic order:

EMMONS, S. F., Livingston to the Snake Plains: Cong. géol. internat., Compt. Rend. 5th session, 1893, pp. 367-374.

Describes geology along route of travel and geologic history of the Snake Plains.

STONE, GEORGE H., An extinct glacier of the Salmon River Range: Am. Geologist, vol. 11, 1893, pp. 406-409.

Describes glacial geology of the Leesburg Basin and the mountains west of Salmon.

ELDRIDGE, GEORGE H., A geological reconnaissance across Idaho: Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1895, pp. 211-276, Pls. XV-XVII.

Describes topography and geology along a route from Boise to Salmon and thence south to Hailey and west to Boise. Includes notes on the ore deposits at Yellow Jacket and the placers of Leesburg Basin and Kirtley Creek.

GOODE, R. U., Bitterroot Forest Reserve: Nat. Geog. Mag., vol. 9, 1898, pp. 387-400, and map. Contains general description of the reserve and definition of mountain systems.

BELL, R. N., The deepest mine in Idaho, the Ramshorn at Bay Horse: Mines and Minerals, vol. 21, 1900, pp. 174-176.

Describes geologic features of the region and occurrence of the silver ores.

LINDGREN, WALDEMAR, The gold and silver veins of Silver City, De Lamar, and other mining districts of Idaho: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 3, 1900, pp. 75-256, Pls. VII-XXXV.

Describes character and occurrence of the igneous and sedimentary rocks and occurrence and nature of the ore deposits of a large area lying south and west of Lemhi County.

BELL, ROBERT, An outline of Idaho geology and of the principal ore deposits of Lemhi and Custer counties, Idaho: Proc. Internat. Min. Cong., 4th sess., 1901, pp. 64-80.

Describes briefly the principal mines of Lemhi and Custer counties, stating amount of development, production, and something of their geologic relations.

RUSSELL, I. C., Geology and water resources of the Snake River Plains of Idaho: Bull. U. S. Geol. Survey No. 199, 1902, 192 pp. 25 pls.

Describes topography, basement series of rocks, recent eruptives, lacustrine deposits, and resources of the area.

LINDGREN, WALDEMAR, A geologic reconnaissance across the Bitterroot Range and Clearwater mountains in Montana and Idaho: Prof. Paper U. S. Geol. Survey No. 27, 1904, 123 pp., 15 pls.

Describes topography and character, occurrence, and geologic relations of the igneous and sedimentary rocks, the structure of the area, and character, occurrence and development of its mineral deposits. Gibbonsville and Mineral Hill districts, Lemhi County, are described briefly.

JENNINGS, E. P., The Lost Packer copper-gold lode (Idaho): Jour. Canadian Min. Inst., vol. 9, 1906, pp. 54-57. Min. and Sci. Press, vol. 92, June 30, 1906, pp. 435-436.

Describes geologic relations and constitution of the Lost Packer vein.

CARR, HENRY C., Vein structure in the Monument mine: Min. and Sci. Press, vol. 96, Apr. 17, 1909, pp. 557-558.

Includes notes on the geology and character and occurrence of the ores at Meyer Cove (Singiser), Lemhi County, Idaho.

UMPLEBY, J. B., Geology and ore deposits of Lemhi County, Idaho: Bull. U. S. Geol. Survey No. 528, 1913, pp. 182, pls. 23.

Describes physiography, general geology, and ore deposits of the county. In the final chapter the nineteen mining districts are treated separately.

GEOGRAPHY.

Situation and access.—Northwestern Custer County, in east-central Idaho, is most easily reached from Mackay, a terminus of a branch of the Oregon Short Line Railroad. Stages run daily except Sunday to Challis, 60 miles distant, and thence on to Bonanza and Custer, 60 and 62 miles farther, respectively. These stage lines are official mail routes, but from Custer the mail is carried by private conveyance 28 miles westward to Ivers, thrice weekly when the smelter is running and twice monthly at other times. Challis may also be reached by stage three times a week from Salmon, 60 miles north, a terminus of the Gilmore & Pittsburgh Railroad.

Settlements.—The region covered by this reconnaissance contains seven settlements, the chief of which is Challis, the county seat of Custer County, in the northeast corner of the area. Challis is an attractive little village of about 1,000 inhabitants and has a bank, two hotels, churches, a good school, and several stores. Adjacent to it are several valleys well adapted for agriculture, which have been settled largely within the last few years. Streams from the mountains afford abundant water for irrigation, and crops of the north temperate latitude flourish. At present the costs of transportation for



A. SALMON CANYON WITH CLAYTON IN THE FOREGROUND.

Looking north.



B. BAY HORSE CANYON AS SEEN FROM A POINT NEAR ITS HEAD

Bay Horse is beyond the second bend.

Licenses are required of all huntsmen, and the charges are so fixed as to favor greatly the residents of the State. Heads and hides may be shipped from the State only by special permit.

History of the area.—The history of northwestern Custer County since its discovery by whites closely involves its mining development. Its early inhabitants were totally dependent upon the mining industry, but other sources of revenue, such as agriculture and grazing, were gradually developed until perhaps most of the present population is independent of the mining industry.

For about 30 years after the discovery of placer gold on Loon Creek in 1868, mining was active and the population was much greater than at present. Custer, Bonanza, Clayton, and Bay Horse were flourishing settlements. More recently Sunbeam prospered, but at present Ivers alone is an active camp.

With the certain revival of mining in the future, agriculture will become much more important, by reason of increased local market and the probability of better transportation facilities.

PHYSIOGRAPHY.

GENERAL RELIEF.

Northwestern Custer County comprises a high mountainous area in which the summits stand about 9,600 feet and the beds of the major streams 5,000 to 6,000 feet above sea level. The mouth of Challis Creek, by railroad location elevations, is 4,830 feet and the mouth of Yankee Fork is 5,905 feet in elevation. The highest point visited in the area, as determined by aneroid, is Estes Mountain, which attains an altitude of 9,800 feet. The highlands form a network of connecting ridges, small areas, and flat-topped spurs. In extent they exceed the lowlands, though steep slopes connecting the two represent most of the surface.

DRAINAGE.

Salmon River, the main artery of this part of Idaho, heads southwest of the area mapped, flows eastward along its southern border, and then abruptly turns to the north and continues along its eastern margin and beyond, finally by an abrupt turn flowing westward across the central part of the State. All the streams of the area are tributaries of Salmon River; most of them join the Salmon at headwaters, but those in the Loon Creek district reach it at a point in the central part of the State, well toward its mouth. Loon Creek Summit and its continuation to the southwest and northeast forms the local divide between northward and southward flowing drainage. Loon Creek and its tributaries have intricately dissected the country north of the divide, and numerous streams, most important among them Yankee Fork, have deeply carved the area south of it.



A. SPUR ON THE NORTH SIDE OF POVERTY FLAT.

Showing the highly inclined beds across which the flat has been developed. The flat is 9,600 feet above sea level.



B. CENTRAL PORTION OF POVERTY FLAT.

The low hills in the background are quartzite; in the foreground is steeply dipping slate.



A. SOUTH WALL OF KINNIKINNICK CANYON AS SEEN FROM POVERTY FLAT.



B. MIOCENE LAKE BEDS NORTHEAST OF POVERTY FLAT.

Note scarcity of vegetation in areas of lake beds.

SUMMIT AREAS.

The uplands are characterized by small flat-topped areas, from which extend square-shouldered spurs, and by level-crested ridges. The striking character of these features has given rise to such local names as "Poverty Flat," applied to a tract 9,600 feet above sea level and about 25 square miles in extent, and "Railroad Ridge," which is more than 100 miles long and so even crested as to resemble, when viewed from a distance, a railroad grade. This ridge lies southeast of the area studied but may be clearly seen from Poverty Flat near Clayton. Equally striking in the evenness of their crests are Antelope Ridge, the Lost River Range, and Lemhi Range—all blending to form the northeastern horizon as seen also from Poverty Flat. To the northwest there are no distinct ranges but instead a veritable labyrinth of small summit areas and short ridges, remarkable for their general accordance in elevation. Poverty Flat itself is a comparatively level tract (Pl. III) bordered by canyons as much as 5,000 feet deep. It is reached with difficulty by trail from Clayton, 4 miles distant, but once on top a wagon could be driven over most of it. A few low quartzite hills rise from its general level and attain a height perhaps 100 feet greater. Along portions of the western and southern borders, notably on a spur west of the New Silver Bell mine, an almost horizontal bench, in places 50 to 100 feet wide but generally rather indistinct, follows along the side slope about 100 feet below the level of the flat. The level part of the flat is deeply mantled with soil, but the quartzite buttes are covered with angular blocks of the underlying material.

This striking summit surface extends across the rocks of the area irrespective of their attitude or composition. The intensely metamorphosed and crumpled schists of the Algonkian, the generally folded slates, quartzites, and dolomitic limestones of the Paleozoic, and the comparatively undisturbed granitic intrusions of the late Cretaceous or early Tertiary have all united to form the present high-level topography. (See Pl. IV.)

The summits of the area, if combined, would determine an undulating plain, differing little in elevation from place to place though here truncating resistant beds and there cutting across shales and schists. The surface could have resulted only from erosion. The area was reduced nearly to base level for the region, where inequalities in rock resistance no longer found pronounced expression in the topography; then it was elevated and dissected by the streams which now drain it.

VALLEYS.

The valleys of the area are of two types—those now occupied by lavas, tuffs, and lacustrine deposits, and those followed by the present streams.

The present valleys of the area are for the most part deep and narrow, but a few have broad floors of gravels in which the streams are now intrenched to a depth of 10 to 50 feet. Valleys of this sort are locally typified by those of Loon Creek and Yankee Fork, but even along Salmon River remnants of deep gravel deposits occur in many places, Robinson Bar being a striking illustration.

The valley of Salmon River is narrow and canyon-like throughout most of its extent, but about Challis it widens, affording broad slopes admirably adapted for agriculture. Antelope Creek, a comparatively insignificant stream, occupies a valley vastly wider than that of Salmon River west of Big Birch Creek. These features are not to be accounted for by difference in rock formations or by structure. They may be interpreted only in the light of a complex drainage history—a history which can be worked out only by physiographic studies broader than those yet undertaken.

Largest among the older valleys is the one crossed by the Ivers Road between points 7 miles south and 5 miles north of Loon Creek Summit. The bedrock of this old valley is exposed at Sunbeam at an elevation of 7,000 feet, but elsewhere it was not seen. If the Sunbeam exposure, which is almost halfway between its margins, is assumed to indicate the general elevation of its bed, the old valley is about 3,000 feet deep and is now filled in most places by lavas and tuffs throughout its width of 12 miles.

About Challis the Miocene lake beds occupy a similar depression but no exposures of its floor are known. Similarly situated topographically are the deposits east of Bay Horse.

RELATION TO ADJACENT TYPES.

The area herein described is a part of that great plateau-like expanse known as the Salmon River Mountains, which is characterized throughout by even summits and deep, narrow canyons carved from rock formations of diverse type and complex structure. Lemhi County, to the north, is continuous with this area and similar physiographically. There the history has been worked out in some detail and broad correlations have been made.¹ The discussion need not be repeated in this bulletin, though the general conclusions are incorporated below.

The old erosion surface represented by the summit levels of the area is known to have extended over much of Idaho and probably into adjoining parts of Montana, Washington, and British Columbia. It has been assigned to the Eocene, both because of the relation of Miocene lake deposits to it, and because of its relation to the Eocene deposits of the Northwest.

¹ Umpleby, J. B., *Geology and ore deposits of Lemhi County, Idaho*; Bull. U. S. Geol. Survey No. 1913, pp. 23-30; *An old erosion surface in Idaho; its age and value as a datum plane*; Jour. Geology, No. 2, 1912, pp. 139-147.

PHYSIOGRAPHIC HISTORY.

The record of the physiographic history of the region is legible for only that comparatively small portion of geologic time since the late Mesozoic. Near the close of the Cretaceous period extensive regional elevation, thought to have been accompanied by folding and great batholithic intrusions, rejuvenated the streams and inaugurated a period of rapid erosion which, by the close of Eocene time, had resulted in a far-reaching surface of gentle topographic forms. The amount of this early Eocene elevation is not definitely determinable, but it was doubtless a few thousands of feet, possibly comparable to that at the close of the same epoch.

Elevation at the close of the Eocene or early in the Oligocene once more rejuvenated the streams of the area. This uplift extended over essentially the same vast area as the former one. In northwestern Custer County the elevation may be taken as about 8,000 feet, or somewhat less than the difference between the present high-level surface and base level for the region. During the Oligocene epoch the major streams developed broad, deep valleys, which in the Miocene and possibly also in part of the Pliocene were the sites of lava flows and lacustrine deposition.

The Pliocene again was a period of dominant erosion. Valleys as much as 4,000 or 4,500 feet deep were locally developed in the Miocene rocks and later shaped by glacial ice.

Ice fields covered the highlands during the Pleistocene, and glaciers extended down the valleys to elevations between 6,500 and 7,500 feet. Below these elevations glacial waters deposited deep and extensive gravel beds, into which many of the present streams are cutting.

Erosion is now active within the region, and perhaps one-third of the task of reducing it once more to an area of gentle topographic forms has been accomplished, this in spite of the far-reaching interruptions of the Miocene epoch.

GENERAL GEOLOGY.

OUTLINE.

The oldest rocks exposed in northwestern Custer County are schists, slates, and quartzites of Algonkian age. Unconformably on these rocks in the eastern and locally in the northwestern part of the area lies a great series, at least 9,000 feet thick, of Paleozoic quartzites, slates, and dolomitic limestones. These were not further subdivided, although there is some reason for thinking that they range in age from Cambrian to Devonian, including ~~the Silurian and Devonian~~ and also the older rocks, are cut by large intrusions of ~~granite~~ ^{granite} and quartz.

diorite, and diorite, which are probably outliers of the great batholith that invaded central Idaho during the late Cretaceous or early Eocene epoch.

Dikes of granite, granite porphyry, and diorite porphyry, closely related in age to the granitic rocks, are locally abundant in the western part of the area. In the central portion and along the eastern margin occur vast accumulations of Miocene lava and tuff, which occupy old erosion valleys. Morainic material covers much of the highland area and extends down the larger valley to elevations of 6,500 or 7,000 feet. Locally it coalesces with outwash gravels deposited along the major streams. (For distribution, see map, Pl. I.

ALGONKIAN ROCKS.

Distribution.—Algonkian rocks are widely distributed in the north-western and south central parts of the area included in the reconnaissance. Perhaps the best exposures of these rocks are along Salmon River, between Thompson and Cold Spring creeks, where for a distance of about 6 miles outcrops are almost continuous. For about 4 miles along Yankee Fork, south from Sawmill Creek, and about the junction of Canyon Creek with Loon Creek, there are also numerous exposures.

Characteristics.—The Algonkian rocks comprise an intensely metamorphosed series of sedimentary deposits, in which schistosity is well developed, in many places to the concealment of bedding structure. Where the attitude of the beds is determinable, however, steep dips, usually away from north-south axes, prevail.

The stratigraphic sequence of the series could not be carefully worked out in the short time available. Along Yankee Fork perhaps 2,000 feet of beds dipping steeply southwestward are exposed between the lavas on the north and the granite on the south. The lower part is dark-gray medium-grained quartzite, and the upper part is composed of thin-bedded blue-black micaceous slates. About Ivers the series comprises sericitic and chloritic schists with interbedded siliceous bands. The three facies of the series—schists, slates, and quartzites—outcrop in the Salmon River section. In the western portion of this exposure bluish-gray fine-grained quartzites are cut off by granite. Below the quartzites are dull black, slightly crumpled slates, which dip 80° W. and outcrop along the road for about 4,000 feet. East of these slates micaceous schists continue to the area about the mouth of Thompson Creek, beyond which Paleozoic formations come in. The relation of the schists to the slates was not observed, although it is believed that they occur lower in the stratigraphic column.

Correlation.—Close correlation of these old metamorphic rocks is not possible from the incidental attention given them during these studies. From their lithologic character and degree of metamor-

phism, however, there is no doubt that they are part of the same general series which is widely exposed to the north in Lemhi County. The rocks there found fall into divisions which accord roughly with the Cœur d'Alene Algonkian section,¹ and it is believed that careful study would reveal approximately the same sequence here.

PALEOZOIC ROCKS.

Distribution.—Beds of Paleozoic age are widely exposed in the eastern half of the area mapped and also occur in a small area south of Ivers in the northwestern portion. The best exposures are along Salmon River, from Thompson Creek to East Fork, and in the walls of Bay Horse Canyon.

Structure.—The eastern area only was studied even in moderate detail. Here three large anticlines and two synclines characterize the structure. The west anticline, later referred to as the Clayton anticline, forms a broad arch between Clayton and Squaw Creek. On the eastern limb the dips are about 80° , and on the western about 45° . Beds which reach the river level at points 2 miles apart are approximately 2,000 feet above it along the axis of the anticline. A similar structural feature about 4 miles wide but with maximum dips to the west and east of 30° and 40° respectively spreads between Clayton and East Fork. It is across this anticline that the erosion-surface of Poverty Flat extends. The third and most important anticline, because of its relation to the ore deposits, extends in a north-south direction through the Bay Horse district, and is designated the Bay Horse anticline. On its east limb the beds dip about 40° and on its west about 80° . Northward within 2 miles the arch flattens, and at the same distance beyond the beds are almost horizontal.

Lithology.—The Paleozoic section is perhaps best exposed in the north wall of Bay Horse Canyon. At Bay Horse the beds are almost horizontal, and in a single cliff at the mouth of Beardsley Creek about 1,000 feet of the section is exposed as follows: At the base lies 300 feet of thinly laminated dark bluish-gray slate, minutely crumpled but without slaty cleavage. Above this is 500 feet of rather massive beds of dolomitic limestone of diverse purity, in some places a dolomite, in other places limestone, and in still others either argillaceous or siliceous. This grades into a thin-bedded slate, about 200 feet of which is here exposed. Westward from Bay Horse the beds are nearly horizontal for about a mile and in the southeast face of Democrat Hill the section may be continued. Here the slate, which is 200 feet thick in the other exposure, is 600 feet thick, and is overlain by dolomitic limestone 1,300 to 1,500 feet thick. About 2 miles above Bay Horse the beds assume a steep westerly dip and this

¹ Ransome, F. L., and Calkins, F. C., The geology and ore deposits of the Cœur d'Alene district, Idaho; Prof. Paper U. S. Geol. Survey No. 62, 1906, p. 27.

limestone in a short distance descends to the creek level. Beyond is a monotonous succession of thin-bedded slates in which slaty cleavage is in many places more conspicuous than the bedding planes. These slates continue for $1\frac{1}{2}$ miles and are cut off by granite. Their average dip is possibly 35° , which if duplication by faulting be negligible, as is thought to be the case, indicates a thickness of more than 4,000 feet. Thus the Paleozoic section as exposed in Bay Horse Canyon is thought to be about 7,000 feet thick.

In the walls of Salmon Canyon, above Clayton, are massive flat-lying quartzites, which extend from the water line upward possibly 2,000 feet and underlie 200 or 300 feet of massive blue dolomitic limestone. These beds do not appear in the Bay Horse section. Thus the total thickness of the Paleozoic section as exposed in this area is more than 9,000 feet, including neither top nor bottom, and with an unspanned break between the two sections studied.

It is possible that the 4,000 feet of slates which outcrop above Bay Horse may prove to be Algonkian, separated from the Paleozoic rocks east of them by a fault, but this is thought improbable, the only suggestion of the relation being their greater metamorphism: metamorphism more likely resulting from the granite intrusion than from the diastrophism which preceded the Paleozoic era. A fault does cross the canyon a short distance above Bay Horse, but the meager evidence secured favors a downthrow on the west. (See Pl. V, B.)

Correlation.—Lithologically the rocks here found agree closely with the Paleozoic formations of the Gilmore section, Lemhi County. There the section comprises between 5,000 and 6,000 feet of beds including 2,000 feet or more of fine-grained Cambrian quartzite, 500 feet of massive Ordovician dolomitic limestone, 300 feet of massive Silurian (?) dolomitic limestone, 2,000 feet of thin-bedded Devonian dolomitic limestone, and at least 300 feet of massive blue limestone of Mississippian age. Comparing the two sections, it seems probable that the quartzite exposed above Clayton agrees with the Cambrian quartzite at Gilmore. The 200 to 300 feet of massive blue dolomitic limestone above it may thus be tentatively correlated with the Ordovician at Gilmore, with which it corresponds lithologically. That portion of the section at Bay Horse does not agree closely with any part of the Gilmore section. In the Bay Horse section there is a group of limestone beds free from dolomite, which affords some basis for thinking that the Mississippian, which constitutes the top of the Gilmore section, is absent. Thus it seems most probable that the Bay Horse section falls between the Ordovician and Mississippian—that is, that the beds probably represent the Silurian and Devonian.

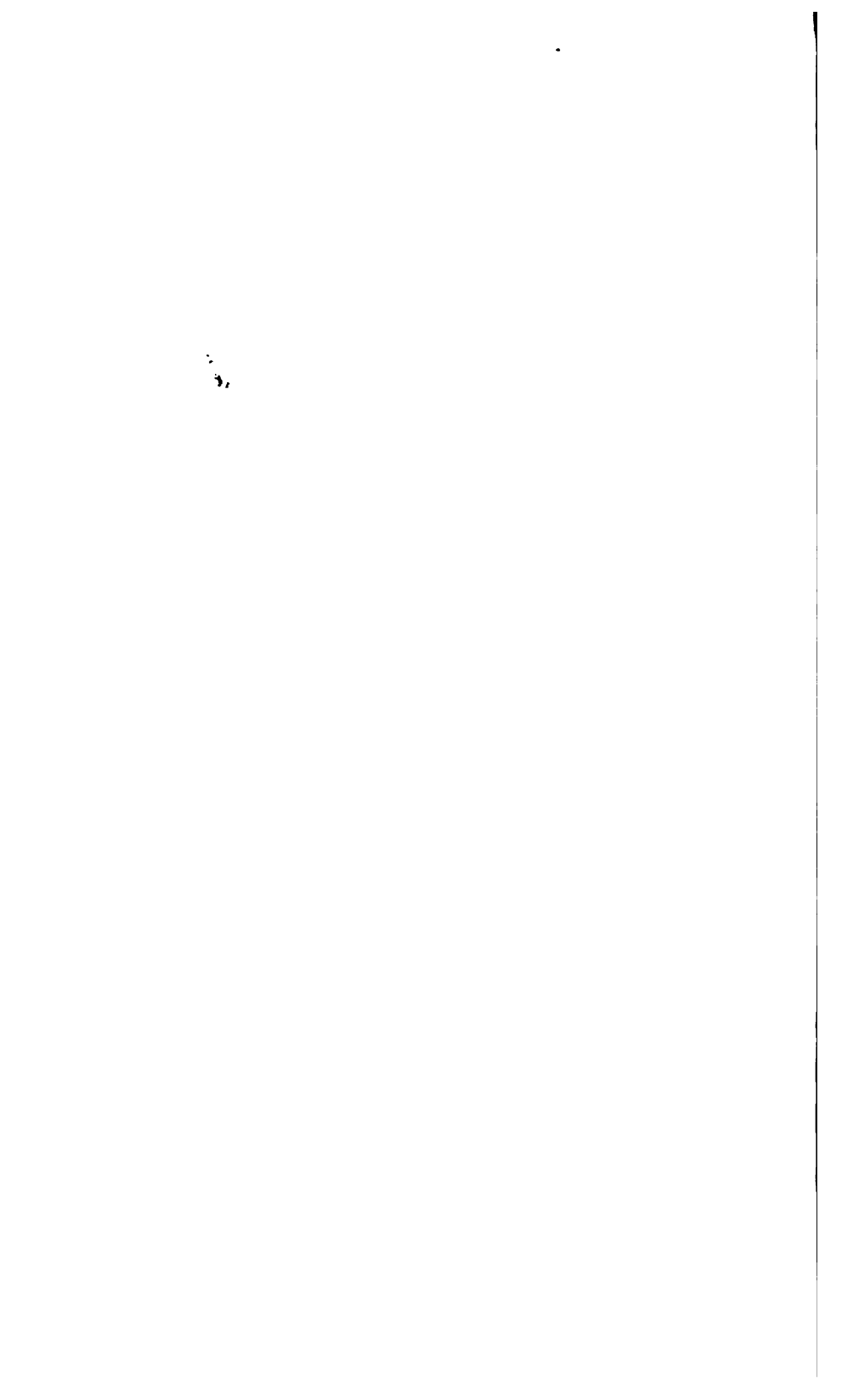
¹ Umpleby, J. B., *Geology and ore deposits of Lemhi County, Idaho*: Bull. U. S. Geol. Survey No. 21913, pp. 32-35.



A. PLEISTOCENE GRAVEL TERRACES ALONG SALMON RIVER BELOW ROBINSON BAR.



B. SLATY CLEAVAGE IN PALEOZOIC (?) SHALES AT ROADSIDE 2 MILES BELOW BAY HORSE CANYON.



If this is true, however, these systems are vastly thicker than at Gilmore. In later work it might be well to entertain as a field hypothesis the possibility that the slates west of Bay Horse are Pennsylvanian and that the Mississippian is there faulted down by the displacement believed to extend northwest across the canyon above Bay Horse.

Fossils were not found, but as only incidental search for them was made, it is not unlikely that the problem may be ultimately solved on fossil evidence. For the present the beds are simply assigned to the Paleozoic, the closer correlations being merely suggestions.

LATE CRETACEOUS OR EARLY EOCENE PLUTONIC ROCKS.

DISTRIBUTION.

Plutonic rocks appear at the surface in the northwestern and south-central parts of the area mapped, also at three localities in the eastern part. In the Loon Creek district a great batholith of quartz diorite extends into the district from the west and again outcrops as quartz monzonite in a belt about 6 miles wide along its eastern border. The largest area of plutonic rock is perhaps that near the junction of Yankee Fork and Salmon River. The main stream in this locality flows between rugged walls of granite for 14 miles below this junction. Northward the area continues for 2½ miles, but to the south and west its extent was not determined. In the Bay Horse district there are three small areas of plutonic rocks. The largest is granite, which comprises a north-south belt about a mile wide that crosses the upper end of Bay Horse Canyon. The other two are diorite, and each is about three-fourths of a mile wide; one crosses Kinnikinnick Canyon 4 miles above Clayton, and the other traverses Salmon Canyon 3 miles below Clayton.

VARIETIES.

The several areas of granitoid rocks differ markedly in composition and in the following paragraphs will be described separately. The rocks were studied hastily in the field and the specimens secured may not be altogether typical. Granite, quartz monzonite, quartz diorite, and diorite are represented.

Granite.—Granite occurs about the mouth of Yankee Fork and near the head of Bay Horse Canyon. Specimens from the former locality are light gray to pink in color, medium grained, and about equigranular, but locally, as near Robinson Bar, there is a marked phenocrystic development of orthoclase, individual crystals attaining an inch or more in length. Megascopically the rock is characterized by its light color and the small amount of biotite compared with the other granitoid rocks of the area. Microscopically examined, it is

seen to contain the following minerals, named in order of decreasing amount: Orthoclase, quartz, microcline, biotite, albite, oligoclase, micropegmatite, muscovite, apatite, magnetite, and rutile. Some of the feldspars show zonal growth from albite, possibly also oligoclase, at the center to orthoclase on the margins. The granite from Bay Horse Canyon is coarse textured and contains much more biotite. It is dark gray in color. Although orthoclase is by far the most abundant feldspar in this rock, albite and oligoclase are both present in amounts about equal to the quartz and biotite. Hornblende, micropegmatite, magnetite, and apatite, may be considered accessory.

Quartz monzonite.—A rock intermediate in composition between the granite and quartz diorite comprises a large area west of Loon Creek Summit. It is commonly medium gray in color, though locally, as near the mouth of East Mayfield Creek, it is dark gray. The darker shades are due to excessive amounts of biotite. In places gneissoid structure is well developed, but this appears only along local zones of shearing. In the thin sections studied orthoclase and plagioclase (oligoclase and less albite) are about equally abundant. Quartz is almost constant in amount and biotite may be either much less or much more abundant than the quartz. Apatite, titanite, and magnetite are the more important accessory minerals.

Quartz diorite.—Quartz diorite is widely exposed south and west of Ivers. It is a dark bluish-gray equigranular rock, rich in biotite. It contains abundant plagioclase (oligoclase and andesine), much quartz, about an equal amount of biotite, and a little orthoclase. Hornblende, apatite, and titanite are accessory constituents.

Diorite.—The diorite in Kinnikinnick Canyon was only seen as float along the east wall, where it is continuous for about three-fourths of a mile. The rock is fine grained, equigranular, and of dark greenish-gray color. The feldspars have approximately the composition of andesine and occur as interlocking lath-shaped crystals. Hornblende is abundant and olivine and augite are almost equal to it in amount.

The other area of diorite occurs east of Clayton. Here the rock is extensively sheared and so highly altered that microscopic study adds little to the field diagnosis. Its texture is equigranular and it consists of andesine and ferromagnesian minerals, the latter completely changed to chlorite and calcite. Its gneissoid structure suggests that it is older than the other intrusive masses, but as older igneous rocks were not found in the area it is grouped with the late Cretaceous or early Eocene plutonic rocks.

AGE AND CORRELATION.

The plutonic rocks of northwest Custer County extend up to the level of the Eocene erosion surface and hence must have invaded the area before the close of the Eocene. On the other hand the

youngest rocks which they cut are the Paleozoic sediments, so that their local geologic relations show only that they are later Paleozoic, Mesozoic, or very early Cenozoic. Broader considerations, however, permit their age to be rather definitely fixed.

Batholithic intrusions are widespread in Idaho. In the central part of the State is a granitic mass more than 20,000 square miles in extent. Numerous smaller areas have been considered outliers from it. Some of these granites are of the same composition, others are more basic, and in one locality granite and diorite have been found to grade into each other.¹ For these reasons, and because nowhere in the State have batholithic intrusions of widely different age been recognized, it is believed that these several types of rock date from the same general period of intrusion and are of the same age as the great Idaho batholith. This batholith has been assigned on what are believed to be sound deductions to the late Cretaceous or very early Eocene,² and it is therefore concluded that the batholithic intrusions of Custer County are also of that age.

EARLY EOCENE DIKES.

DISTRIBUTION.

Dikes are abundant only in the northwestern part of the area, in the immediate vicinity of Ivers, where 10, averaging perhaps 30 feet in width, have been encountered in the workings of the Lost Packer mine. Most of these dikes are approximately parallel and dip northwest at about 40°. In the Yankee Fork district dikes of this age were not recognized, and in the Bay Horse district but one was noted. This is a narrow intrusion which appears in the lowest tunnel of the Ramshorn mine.

VARIETIES.

The dikes fall into three general groups—granite, granite porphyry, and diorite porphyry. Included in the last is the peculiar rock which occurs in the Ramshorn mine and which is designated an augite melaphyre. The several groups will be briefly described.

Granite.—Granite dikes, in places 30 feet wide but generally about 10 feet across, parallel the ore body on the hanging-wall or footwall side in parts of the Lost Packer mine. The rock has been greatly crushed, but the constituent minerals are readily determinable. It is light gray, inequigranular—due to a phenocrystic development of the feldspars—and consists of microcline, orthoclase, quartz, and

¹ Lindgren, Waldemar, The gold and silver veins of Silver City, De Lamar, and other mining districts Idaho: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 3, 1900, p. 195.

² Umpleby, J. B., An old erosion surface in Idaho; its age and value as a datum plane: Jour. Geology, vol. No. 2, 1912, pp. 139-147.

muscovite, decreasingly abundant in the order named. Ferromagnesian constituents are rare.

Granite porphyry.—Granite porphyry, younger than the granite dikes (fig. 4, p. 95), occur in the Lost Packer mine as flat-lying bodies 20 to 40 feet wide. It is a medium-gray rock with phenocrysts and groundmass about equal. The degree of alteration of the specimens studied leaves some doubt as to whether the rock might not better be called a quartz monzonite. Most of the feldspars seem to have an index lower than Canada balsam, but a few are certainly higher. Quartz exceeds biotite and hornblende is rare.

Diorite porphyry.—Several flat-lying dikes of diorite porphyry about 20 feet wide occur in the Lost Packer mine. They are intermediate in age between the granite and granite porphyry. The rock is dark gray, rather mottled by the lighter-gray feldspar crystals. The feldspars are predominantly andesine, though in some of the thin sections labradorite appears and in others oligoclase. Biotite is abundant, though in few specimens conspicuous. Quartz and apatite are the principal accessory minerals. Locally, as in No. 3 tunnel, marginal phases of the rock contain a large amount of augite.

The small dike that is cut about 200 feet from the face of the lowest Ramshorn tunnel differs from the others in that augite, its only recognized mineral, studs a groundmass itself containing much augite. A few other phenocrysts, now completely altered—largely to calcite—were probably feldspars.

AGE OF THE DIKES.

All the dikes above described are cut by the Eocene erosion surface. On the other hand the granite dikes are probably almost contemporaneous with the granitic batholiths; if there is any difference in age, they are a little younger. The other dikes are still younger than these. As the granitic rocks are assigned to the late Cretaceous or early Eocene the dikes are thus believed to have entered during the early part of the Eocene epoch. It further follows that they entered in fairly rapid succession, the sequence being granite, diorite porphyry, granite porphyry.

MIOCENE VOLCANIC ROCKS.

DISTRIBUTION AND CHARACTER.

Lavas and tuffs extend as a broad belt northeast through the central part of the area covered by this reconnaissance. They fill completely an Oligocene erosion valley which, where traversed by the road to Ivers, is 12 miles wide and about 3,000 feet deep. Lavas and tuffs also form broad areas in the northeastern and eastern parts of the Bay Horse district. Here also they occupy erosion valleys,

but in no place were they seen to reach the level of the Eocene surface.

The general sequence of volcanic rocks seems to be andesites and latites, followed by andesitic and rhyolitic tuffs, and these in turn followed by basalts. In the western part of the Yankee Fork district the series is chiefly tuff, but east of Custer lava flows appear in the canyon sides through a vertical range of several hundred feet. The extrusive rock above the Lost Packer mine is quartz latite, and that near the lower end of the Loon Creek placers is andesite. About Challis and east of Bay Horse both lavas and tuffs are abundant, and in them the major sequence is from lavas, presumably andesites, to tuffs. East of Bay Horse, however, basalt dikes cut the tuffaceous material and locally spread out as flows on its upper surface.

The dearth of rhyolites in this area is in striking contrast to the great amount of this rock which appears about Parker Mountain, in Lemhi County.¹ The two areas are said to be continuous, yet the prevailing type of rock is very different. In each locality 2,000 feet or more of the series is exposed. About Salmon, still farther north, however, andesites are abundant,¹ and this area also is believed to be continuous with that at Parker Mountain. The several rocks will be described briefly.

ANDESITES AND LATITES.

Latite was not recognized from microscopic examination, but one specimen, thought from the thin section to be a dacite, proved on partial analysis to contain 3.26 per cent of potassium oxide, and another, which appeared to be a normal andesite, was found to contain 3.86 per cent of potassium oxide. (See p. 26.) In these specimens, the only ones analyzed, the potash is evidently in the groundmass, which leads to the belief that many of the rocks herein described as andesites will prove, on chemical analysis, to be latites. Thus the two groups are described jointly.

The rocks range in color from dark gray through various shades of purple to bluish black, perhaps a brownish-gray variety being most abundant. Phenocrysts and groundmass comprise about equal areas. The minerals of the groundmass are determinable in but few specimens. Among the phenocrysts feldspar predominates, though some ferromagnesian mineral is generally conspicuous. The feldspars are commonly oligoclase and andesine, but a few crystals of labradorite are present. In a specimen taken near Jensen's bridge, in the Bay Horse district, hypersthene, biotite, and augite occur with andesine. A rock from the mouth of Jordan Creek contains much pyroxene and a little olivine. In another specimen, obtained near the

¹ Umpleby, J. B., *Geology and ore deposits of Lemhi County, Idaho*: Bull. U. S. Geol. Survey No. 528, 1913, p. 47.

Badger mine, augite is abundant. A dark-gray rock at the head of Bay Horse Canyon contains conspicuous amounts of biotite and hornblende. Partial analyses of two of the rocks included in this group appear below:

Partial analyses of volcanic rocks from northwestern Custer County, Idaho.

[R. C. Wells, analyst.]

	1	2	3
SiO ₂	60.58	64.20	80.47
CaO.....	4.31	3.99	.14
Na ₂ O.....	3.86	3.40	.16
K ₂ O.....	3.86	3.26	3.80

1. Latite, taken from roadside 1 mile below Sunbeam. Phenocrysts < microcrystalline groundmass. Feldspar Ab₇₅An₂₅. A little augite as small anhedral crystals. Biotite and magnetite accessory. Calcite and iron oxide secondary.

2. Quartz latite, taken above Lost Packer mine. Phenocrysts < cryptocrystalline groundmass. Feldspar about Ab₇₀An₃₀. Scattered grains of quartz and less biotite. Chlorite, calcite, and iron oxide secondary.

3. Rhyolitic tuff, taken on west slope, 200 feet below Loon Creek Summit, at roadside. Very fine grained, fragmental, mostly glass. A few feldspar grains, all with higher index of refraction than Canada balsam.

TUFFS.

The tuffs of the area are fine-grained rocks of dull-white to reddish color and generally form steep chalky white slopes. They are well exposed on the west face of Estes Mountain, where for several hundred feet below its summit vegetation is meager. In the Yankee Fork district the tuffs are commonly massive, but about Challis they are thin bedded and interstratified with seams of clay that are again referred to in connection with the lacustrine deposits.

The tuffs are commonly fine grained and composed of angular fragments of glass, quartz, and feldspar, together with a few needles of hornblende and scales of biotite. The feldspar grains are commonly striated and have an index of refraction higher than Canada balsam, but the only specimen submitted for partial analysis contains 3.80 per cent of potash and less than 1 per cent each of soda and lime. It is clearly a rhyolitic tuff. That some of the tuff, however, is andesitic or at least latitic is shown by the abundance of the striated feldspar fragments. The tuffs near Challis have been described petrographically by A. A. Julien.¹

AGE OF THE LAVAS AND TUFFS.

The lavas and tuffs of northwest Custer County are assigned to the Miocene for the following reasons: They occupy valleys developed after the elevation of the Eocene erosion surface. If the Oligocene be allowed for the development of these valleys the lavas and tuffs are post-Oligocene. On the other hand, glacial ice occupied the

¹ Volcanic tuffs of Challis, Idaho: Trans. New York Acad. Sci., vol. 1, 1882, pp. 49-53.

upper parts of the valleys carved in the volcanic rocks. Some of these preglacial valleys, as Yankee Fork and Jordan Creek, are 3,000 feet or more deep. It therefore seems probable that much of Pliocene time was consumed in their development.

MIocene LACUSTRINE DEPOSITS.

Distribution.—Lacustrine deposits occur in the northeastern and eastern portions of the area studied. The northern area comprises an irregular belt about 10 miles across, with tongues reaching up the several valleys tributary to the basin in which Challis is situated. To the south, west, and north the lake beds give way to lava flows, but to the southeast they connect across a low divide at the head of Antelope Valley, with similar deposits in the valley of Big Lost River. The area east of Bay Horse is of peculiar shape, but seems to have an outward continuation south of Antelope Ridge.

Character.—Perhaps the best exposures of these beds are along the east bank of Salmon River below Challis. Here the bluffs are about 200 feet high, and as seen from across the river are made up of light gray sandstones, probably tuffaceous, and dove-colored shales. Conglomeratic members are sparsely and irregularly distributed through the section. The beds vary in thickness from less than an inch to several feet. In bluffs north of Challis tuffaceous material, generally very fine grained and of green, gray, and white color, predominates. It is nicely bedded, in places thinly laminated.

The hurried observations afforded little idea of the thickness of the deposits, although it must unquestionably be hundreds of feet.

Age.—Fossils were not found in this area, but the topographic relation of these beds is similar to those at Salmon, which were assigned to the Miocene on floral evidence.¹

PLEISTOCENE DEPOSITS.

Morainic material.—The highland parts of the area in most places are covered by loose unsorted rock material, locally overlying distinctly striated rock surfaces. The innumerable valleys and canyons which head at elevations greater than 7,500 or 8,000 feet are terminated by cirques, widely different in size and many of them occupied by small lakes. Below these the canyons are U-shaped, strewn unequally with detrital material, and in many places followed by low hummocky ridges roughly parallel to the base of the walls. Deposits of this sort extend down the larger valleys to elevations of about 7,000 feet, rarely to 6,500 feet, as in Bay Horse Canyon.

These several features clearly indicate glacial action. The ice probably covered all the areas above 8,000 feet and attained the lower levels only in the form of alpine glaciers.

¹ Umpleby, J. B., *Geology and ore deposits of Lemhi County, Idaho*: Bull. U. S. Geol. Survey No. 528, 1913, pp. 28-39.

Outwash material.—The valleys of Yankee Fork from Custer to Salmon River and of Loon Creek, at least from Cottonwood Creek headward for 10 or 12 miles, are filled to a maximum known depth of 90 feet (see p. 80) with roughly sorted rounded to subangular material derived from the adjacent highlands. These deposits indicate a change from conditions of erosion, as shown by the existence of the valleys which they occupy, to conditions of deposition; there was a transition from degradation to aggradation. Such a change may take place conceivably in many ways, but the essential factor must be either a decrease in stream velocity or an excess of available material. The presence of the deposits in great valleys developed within areas of Miocene lavas shows that the deposits are Pliocene or later.

Erosion preceded the formation of the deposits and erosion is now removing them, hence it is reasonable to look to the Pleistocene, a period of special climatic conditions, for an explanation of their presence. At this time glacial ice operating on the highlands and within the upper parts of the valleys was loosening and grinding up vast quantities of material, some of which has not yet been removed. During the general period of ice advance much of this was covered by the ice and protected, although even then vast amounts of material were doubtless available for transportation. Not, however, until the general period of ice recession commenced did the supply of available material reach its maximum, and at this time, also, the run-off from the glacier areas was greatest, and the streams fully loaded in their upper, swifter portions, must have deposited their load farther downstream, where the gradient was less. It is therefore believed that the great gravel deposits of Loon Creek and Yankee Fork valleys are of late Pleistocene age.

RÉSUMÉ OF GEOLOGIC HISTORY.

The earlier geologic history of northwestern Custer County, Idaho, comprises a record of long-continued sedimentation, followed by strong regional metamorphism and erosion in the pre-Cambrian. In the Paleozoic, again, sedimentation was the dominant feature, and some time after its close great dynamic movements developed folds whose limbs now commonly dip about 45° away from general north-south axes. In so far as the record is legible, erosion was the dominant feature during the Mesozoic, but near its close great batholithic intrusions entered beneath the area. Their invasion is believed to have been expressed at the surface by a pronounced elevation, which during the Eocene was planed well toward the base-level of erosion.

The Eocene surface of gentle topographic forms was soon elevated 7,000 or 8,000 feet, and deep valleys developed by the close of the Oligocene. During the Miocene, volcanic activity was rife; vast quantities of lavas and tuffs filled the larger valleys, some of them more than 3,000 feet deep. Incident to the lava eruptions many of

the streams were impounded, and lakes corresponding in shape to former valleys ramified among the mountains. In these lakes muds, sands, and volcanic ash accumulated to great depths during Miocene time. During the Pliocene epoch erosion once more became dominant, but accompanying it were the dying stages of the volcanic activity which characterized the Miocene. The Pleistocene was an epoch when destruction of the highlands exceeded erosion along the main arteries. Glacial ice covered the summits and occupied the heads of canyons. More material was supplied than could be carried onward by the larger streams, which along their lower courses deposited vast beds of gravels, ready for removal when conditions of erosion once more became normal.

The deposition of metallic ores followed both the late Cretaceous or early Eocene and the Miocene igneous activity. The former resulted in gold-copper, silver-copper, and lead-silver deposits; the latter in gold-silver veins.

ORE DEPOSITS.

GENERAL FEATURES.

Character of the deposits.—The ore deposits of northwest Custer County comprise gold placers and lodes carrying gold-silver, gold-copper, silver-copper, and lead-silver ores. The first, second, and third types of lodes are typically fissure fillings, but the fourth might equally well be considered of replacement origin, the solutions, however, directed largely by fissures. Thus they are all characteristically of tabular outline.

In most of the deposits the ore is of excellent grade, little of that which has been mined affording a return of less than \$30 to the ton and some of it \$500 or \$600. Perhaps most of the production of the area has come from ores worth \$50 to \$100 to the ton.

The gold-silver deposits are characterized by a highly siliceous gangue; the others by a siderite gangue. The former also present much more intense metasomatic alteration of the wall rock than the others.

Periods of mineralization.—Two distinct periods of mineralization are recognized. These periods were separated by a long interval in which the area was reduced to gentle topographic forms, elevated several thousand feet, further dissected, and many of the valleys filled or partly filled with volcanic material. The deposits of the two periods are distinct in character and their age relations so clearly determinable that in the following sections age is taken as the basis of major classification, and the deposits are grouped as pre-Oligocene and post-Oligocene. Great difference in age with profound erosion intervening shows that the older deposits must have been formed at vastly greater depth than the younger, a fact thought to account for

conspicuous differences in the structure of the ores and probably also in the mineralogy of the two groups of deposits.

Distribution.—Ore deposits are widely distributed in the northwestern part of Custer County. In the Loon Creek district they are largely grouped around Ivers, near which town gold placers, gold-copper veins, and lead-silver veins are recognized. In the Yankee Fork district the old mining towns of Custer, Bonanza, and Sunbeam are each centrally situated with respect to gold-silver veins. Near Bonanza gold placers occur. In the Bay Horse district the deposits are more widely distributed, but here Bay Horse, Clayton, Squaw Creek, and Slate Creek may be taken as centrally situated with reference either to silver-copper or lead-silver deposits.

Little is known of the country intermediate between these widely separated localities. In the early days much of it was run over by the prospector, but there is little evidence in the way of prospect pits to show that it was seriously examined. Many outlying deposits may yet be discovered.

Geologic relations.—The oldest rocks known to be exposed in the area are Algonkian schists, slates, and quartzites, widely distributed in the south-central and northwestern portions. These rocks are overlain unconformably by a great series, more than 9,000 feet thick, of quartzites, dolomitic limestones, and slates, of Paleozoic age. These are most widely exposed in the Bay Horse district, but are also present south of Ivers in the Loon Creek district. The next younger rocks are the batholithic intrusions which are assigned to the late Cretaceous or early Eocene. These appear at the surface as an area of quartz diorite near Ivers; an area of quartz monzonite between Ivers and Sunbeam; a broad expanse of granite about the mouth of Yankee Fork and a smaller mass near the head of Bay Horse Canyon; and two small areas of diorite, both near Clayton. The boundaries of the several intrusions are not indicated completely on the map, but in general terms these types may be considered to form the surface rock over about 10 per cent of the area.

Closely related to the batholithic intrusions are the granite, granite porphyry, and diorite porphyry dikes, which are numerous only in the vicinity of Ivers.

The youngest rocks in the area, exclusive of glacial débris, are tuffs, lavas, and lacustrine deposits of Miocene and possibly in part Pliocene age. The largest area of these extends northeast-southwest through Yankee Fork district. Here an old valley, some 10 miles wide and 3,000 feet deep, is filled with latites, andesites, and tuffs, the latter locally nicely stratified. In the east-central and northeastern parts of the area are other widespread deposits of this age, but in these localities clastic material is of equal abundance with the tuffs and lavas.

Deposits of ore occur in all the groups of rocks above mentioned. The late Tertiary eruptives inclose the gold-silver veins of the Yankee Fork district. Granite is the inclosing rock of part of the lead-silver deposits south of Ivers. Formations of Paleozoic age inclose the lead-silver and silver-copper deposits near Clayton and Bay Horse. Algonkian schists constitute the country rock for the gold-copper deposits and may also inclose the lead-silver veins of the Livingston group.

PRE-OLIGOCENE ORE DEPOSITS.

CLASSIFICATION.

The pre-Oligocene metalliferous deposits of northwestern Custer County may most advantageously be classified, according to the principal metals which they contain, as silver-copper, lead-silver, and gold-copper deposits. The three types have much in common and mineralogic gradations between them occur locally, but as groups they are exceptionally well characterized by their leading metals. The features which they have in common are (1) a siderite gangue; (2) similar paragenesis, the general order being iron carbonate followed by quartz, the metallic sulphides, and sulphantimonites; (3) subordinate metasomatic alteration of the wall rock when compared with the post-Oligocene deposits; and (4) a close accordance with one another in age.

The kind of inclosing rock may also be taken as the basis for classification, but this only separates, and that incompletely, the lead-silver deposits from the others. Such a classification comprises (1) deposits inclosed in calcareous and dolomitic rocks, and (2) those inclosed in slates and schists. The first includes the lead-silver deposits, the second those carrying silver-copper and gold-copper ores. The classification according to metals contained is followed in the later discussion.

SILVER-COPPER DEPOSITS.

DISTRIBUTION AND HISTORY.

Deposits of silver-copper ore have been found only in the Bay Horse district, where the two most important mines—the Ramshorn and Skylark—produce ores of this kind. In addition to these mines the lodes of the New Silver Bell mine, one of the Hoosier veins, and some small deposits near the head of Garden Creek are of this type.

The Ramshorn vein, located in August, 1877, was the first deposit of this type recognized in Custer County. A short time thereafter the Skylark and Silver Bell were staked and for 20 years following these and the Ramshorn were active producers. Although during recent years but little ore of this type has been mined, there is

more of it blocked out in the area than of any other type. In all about \$6,250,000 has been derived from this ore; approximately \$625,000 from copper, the balance from silver.

GEOLOGIC RELATIONS.

All the silver-copper deposits are inclosed in slates, probably of Paleozoic age, whose cleavage, forming high angles with the bedding planes, is commonly well developed and locally is more conspicuous than the bedding structure.

Granite outcrops a few hundred feet west of the Skylark and Ramshorn veins, but no igneous rock was noted in the immediate vicinity of the Silver Bell deposits.

FORM AND STRUCTURE OF THE DEPOSITS.

The silver-copper ores occur in tabular deposits which range in width from a few inches to 4 feet, averaging perhaps 20 inches. They are bounded by well-defined walls and the few offshoots follow bedding or joint planes. Their general strike is north-south and the dip either to the east or to the west. The dip of the veins is largely determined by lines of parting which antedate the period of fissuring. The Ramshorn vein follows the slaty cleavage of the inclosing rocks: the Skylark occurs along a bedding plane; but the New Silver Bell is independent of either cleavage or bedding planes, the fissuring here cutting across the flat-lying beds at a low angle in the upper part and a considerable angle in the lower part. (See Pl. VI.)

THE ORES.

PAY SHOOTS.

Within the veins the ore occurs in shoots of irregular shape which range in length from 15 or 20 to 200 or 300 feet, and in width from a few inches to 4 feet, averaging perhaps 20 inches. The vertical extent of the shoots generally exceeds the horizontal and in many places, as in the Skylark mine, the shoots are distributed one above the other along roughly parallel lines. The portion of the fissures intermediate between the shoots is locally filled with gangue or gouge, equal in width to the ore, but in most such places the walls are close together and only a narrow selvage marks the fissure.

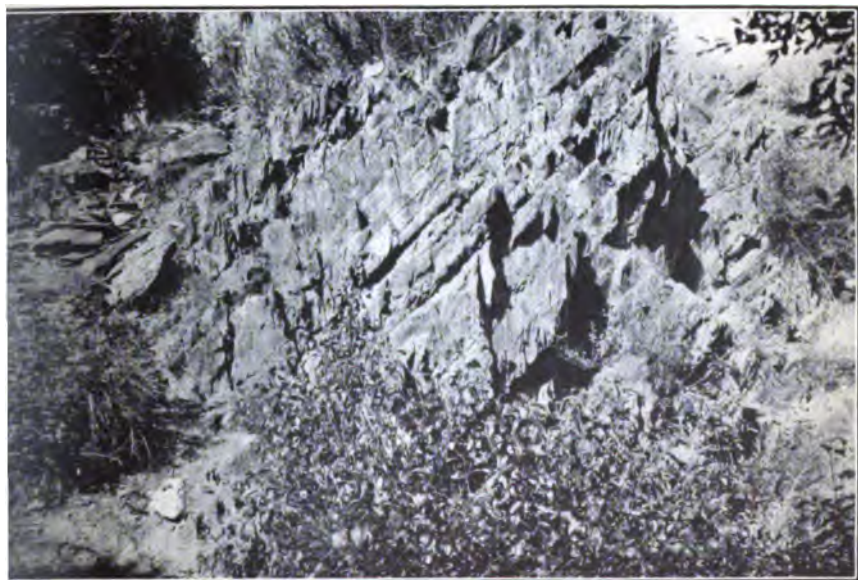
MINERALS.

Relative abundance.—The ore is characterized by tetrahedrite in a siderite gangue. Associated with these minerals, but in very subordinate amounts, are quartz, chalcopyrite, galena, arsenopyrite, pyrite, and sphalerite. Within the deposits as now worked secondary minerals are negligible, although in the upper levels cerargyrite was present in large amounts. It is said that there, too, lead was much more abundant than in the present ore.



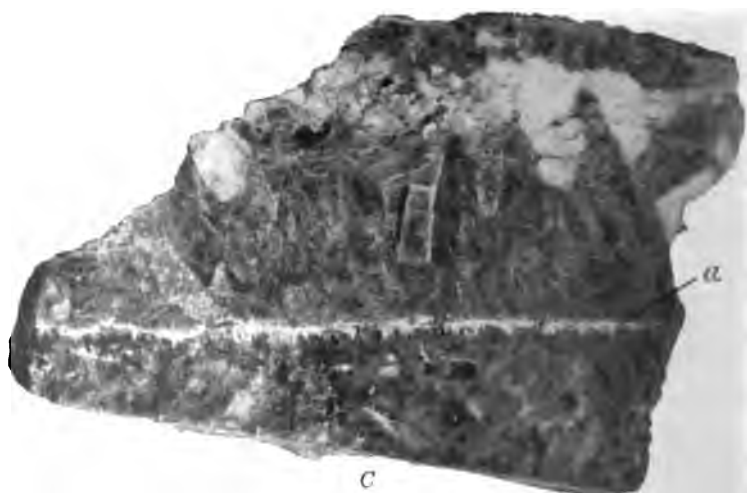
A. RAMSHORN AND SKYLARK MINES, BAY HORSE DISTRICT.

The strike of the Ramshorn vein is shown by the series of dumps on the right.
The Skylark dumps are shown at the left, in the upper part of the view.



B. DETAIL OF STRUCTURE NEAR THE RAMSHORN AND SKYLARK MINES.

Showing slaty cleavage, followed by the Ramshorn vein and bedding planes followed by the Skylark vein.

**A****B****C**

SPECIMENS OF ORE FROM UTAH BOY NO. 5 TUNNEL, RAMSHORN MINE.

- A**, Tetrahedrite (dark areas) and siderite (light areas). Films and veinlets of chalcopyrite occur along the crack in the siderite. Natural size.
- B**, Euhedral crystals of quartz in nicely crystallized siderite. Natural size.
- C**, Along the fracture (a) is a veinlet of arsenopyrite with columnar crystals replacing the inclosing siderite. Near the top is quartz intergrown with the siderite. Natural size.

In addition to the minerals which are confined to the fissures, the vein solutions have developed certain others in the inclosing rock. Among the minerals here formed sericite alone is abundant, but as it characterizes the slates well removed from the fissures, the extent to which it is due to the ore-bearing solutions is difficult to determine. Perhaps the best basis for comparison is the state of preservation of minerals other than sericite which were developed by the earlier metamorphism. Of these an andalusite-like mineral¹ is excellently preserved in the slates well removed from the fissures, but near them this mineral is completely altered to sericite and calcite. Thus in thin sections taken near the vein sericite of two generations is thought to be present; the earlier resulted from regional metamorphism, the later represents metasomatic alteration by vein solutions. Accompanying the sericite are numerous small opaque specks which in reflected light are dull gray. They were not identified.

Paragenesis of the vein minerals.—The sequence of formation of the more abundant vein minerals is rather definite, but among the accessory minerals the order is recurrent. Siderite is clearly the earliest mineral formed. It was closely followed by tetrahedrite, which occurs along fractures in the siderite and occupies embayments in it, but in a few places the two are so intergrown as to suggest contemporaneous deposition. Arsenopyrite bears the same relation to siderite as does tetrahedrite, but their relation to each other is not known. Quartz occurs both as massive intergrowths with the siderite and tetrahedrite and as doubly terminated prisms either occupying small cavities in the tetrahedrite or embedded in the siderite. Chalcopyrite occurs principally as narrow films along fractures and as tetrahedrons lining cavities in the tetrahedrite, but locally seems to be intergrown with that mineral. In many places a narrow band of chalcopyrite separates the tetrahedrite from the siderite. Galena is found as isolated grains in the tetrahedrite but most commonly occurs as bunches partly filling cavities an inch or more across. Pyrite is extremely rare, but a few crystals were noted embedded in the siderite. In such places it was formed later than the tetrahedrite, but before the chalcopyrite, the latter mineral in some specimens coating it. Upon some of the free faces of the galena are small crystals of sphalerite so thickly spaced as to form a drusy surface. They appear to be entirely superficial, for in no place were they seen to extend into the galena. Also among the last minerals to form are small lamellar crystals of siderite, which protrude from the sides of small cavities along the margins of siderite areas. (See Pl. VII.)

Thus the general sequence of deposition was from carbonate to ulphantimonite to sulphides, the order of formation of the sulphides

¹ The index of refraction is $1.62 \pm$, whereas andalusite (mean) is 1.638. A few sections also give an inclined extinction up to 11° .

being iron-copper, lead, and zinc. It is noteworthy that pyrite is rare in the deposits, but arsenopyrite is very generally present, though nowhere abundant.

Composition of the tetrahedrite.—Tetrahedrite, commonly known as gray copper ore, is a sulphantimonite of copper in which the copper is commonly replaced in part by iron, zinc, lead, mercury, silver, manganese, nickel, and the antimony by arsenic and bismuth. It is widely distributed in metalliferous deposits but is usually an accessory constituent. Perhaps the largest deposits in the United States heretofore described are those of the Sheba and De Soto mines in Humboldt County, Nev. Here, however, the principal ore mineral was jamesonite.¹ Tetrahedrite is also found at many localities in Colorado, Mexico, Bolivia, and Chile, and in numerous deposits in Europe.² So far as the writer has been able to ascertain, however, no locality has been described which has produced an amount even comparable to the \$6,250,000 derived from the three deposits of this mineral in the Bay Horse district. Of this amount \$3,000,000 came from the Ramshorn mine, in which a large tonnage yet remains.

The tetrahedrite here found is dark gray with splendid luster on fresh fracture and metallic luster after moderate exposure. It is massive in its occurrence; in no specimen was a crystal face seen. Numerous fairly smooth planes appear on the specimens, but the arrangement of these is such as to indicate fracturing instead of cleavage. Locally such faces are doubtless due to juxtaposition with siderite.

A complete analysis of the tetrahedrite from Utah Boy No. 5 level, Ramshorn mine, was made in the Survey laboratory by R. C. Wells. The material was carefully selected to preclude chalcopyrite, the only mineral likely to be intermixed with it. The analysis follows:

Analysis of tetrahedrite from Ramshorn mine, Custer County, Idaho.

[R. C. Wells, analyst.]

Gangue.....	0.08
Sulphur.....	25.74
Silver.....	4.86
Bismuth.....	.34
Arsenic.....	1.46
Antimony.....	25.22
Copper.....	33.39
Iron.....	4.64
Zinc.....	3.53
Manganese.....	.01
Nickel.....	tr.
	99.27

¹ Ransome, F. L., Notes on some mining districts in Humboldt County, Nev.: Bull. U. S. Geol. Survey No. 414, 1909, p. 43.

² For a list of localities and numerous analyses, see Hintze, Carl, Handbuch der Mineralogie, vol. 1, 1903, pp. 1082-1120.

If the analysis is calculated in molecular quantities the following proportions result: Sb(Bi,As), 1; Cu (all other metals), 3.03; S, 3.48. The theoretical proportions for tetrahedrite are 1.3.3, but a study of available analyses¹ shows that sulphur is commonly in excess. In this tetrahedrite, however, the excess is greater than in any of the analyses which have been examined. Chalcopyrite is the only mineral which, from metallographic studies, can reasonably be assumed to be present as an impurity, but to calculate the excess sulphur as that mineral uses up all the iron in addition to an equal number of copper molecules, and thus reduces, beyond reason, the molecular value of the copper component. From these calculations it is concluded that the analysis was of essentially pure tetrahedrite and that the excess of sulphur, if significant, may be in solid solution or possibly combined as a higher sulphide of one or more of the metals.

Vertical distribution of minerals.—Throughout the workings now safely accessible there is no appreciable difference in the mineralogic association with depth from the surface. The lowest level of the Ramshorn mine is 1,650 feet vertically below the apex of the vein. From the lowest tunnel up to the Utah Boy No. 3, a vertical distance of about 900 feet, the tunnels were explored; above are abandoned stopes. In this lower half of the mine the relative amount of the several minerals, so far as observed, is constant. Of the mineralogic make-up of the ore from the old workings there is no available record. A brief note on the Ramshorn deposit when only two tunnels had been driven² states that the better grade of ore ran 500 ounces in silver per ton and 16 per cent of lead, no mention being made of copper. This probably means an abundance of cerargyrite and sand carbonate near the outcrop, but whether that part of the vein once contained copper as well as lead can not be determined from such a statement, for the copper, if formerly present, would readily have been leached during the formation of cerargyrite and sand carbonate. A zone of secondary chalcocite below the oxidized ore would support the opinion of the writer that tetrahedrite once extended up to and beyond the level of the present surface. No information was procured concerning the mineralogy of the zone between the oxidized ore and the primary ore now exposed. It is said, however, that most of the production has come from ores similar to those now developed.

AGE AND GENESIS.

The three principal silver-copper deposits are truncated by the Eocene erosion surface and hence were formed at least before the close of the Eocene. On the other hand, they have much in common with

¹ Kretschmer, A., *Analyse und chemische Zusammensetzung der Fahlerze*: Zeitschr. Kryst. Min., vol. 48, No. 5, 1910, pp. 484-513.

² News note, Min. and Sci. Press, Oct. 2, 1880, p. 220.

the lead-silver deposits and are thought to have been deposited during the same period of mineralization. As in the Loon Creek district some of the lead-silver veins are inclosed in granite, it is probably safe to assume that the silver-copper deposits are postgranitic even though the youngest rock inclosing them is of Paleozoic age. The granite is pretty surely of late Cretaceous or early Eocene age, hence these deposits are believed to date from the late Cretaceous or early Eocene. This assignment is compatible with the age of deposits in Idaho of similar type though somewhat different mineralogically, which have been described elsewhere.

The depth at which the deposits were formed can not be definitely determined, but it is certain that a vast amount of erosion has taken place since their deposition. In the development of the Eocene erosion surface several thousand feet of beds must have been removed; a conclusion which follows from a study of the anticlinal structures truncated. Another line of suggestion is based on the belief (p. 24) that the granitic intrusions accompanied the profound elevation of the surface which inaugurated the rapid erosion of the Eocene epoch. The cover was entirely removed from the batholiths over broad areas and the igneous rock itself deeply planated. Still another line of attack is based on the accumulation of great fluvial deposits in adjacent areas during the Eocene. The region must at that time have been sufficiently elevated for the efficiency of the streams in transporting sediments to be far greater within the area than beyond it. From these several lines of evidence it is believed that 5,000 feet may be taken as a safe minimum estimate of the amount of Eocene erosion. Thus the highest deposits are thought to have been formed at a depth of at least 5,000 feet, probably much deeper, and the lowest ones at a depth 3,000 feet greater. These figures correspond closely to those thought by Ransome¹ to be applicable at Cœur d'Alene.

The temperature at which the deposits formed can not be known even approximately, although the normal temperature gradient for increasing depth below the earth's surface places a minimum of about 100° C. for a depth of 8,000 feet. The proximity of the cooling granitic mass which now outcrops within 600 feet of the deposits must have raised this temperature greatly. Therefore, in any consideration of genesis high temperature and, because of the depth, high pressure must be assumed.

There is abundant reason for believing that the deposits were formed from solution. The two other possibilities, namely, volatilization and a melt, are ruled out by the mineral compounds of the deposits. The carbonate gangue is incompatible with the conception of a melt.

¹ Ransome, F. L., and Calkins, P. C., The geology and ore deposits of the Cœur d'Alene district, Idaho: Prof. Paper U. S. Geol. Survey No. 62, 1908, pp. 139-140.

and the difficulty of volatilization of the metals in the right proportions, even when combined, eliminates the other hypothesis.

The most striking feature of the deposits is the great quantity of tetrahedrite, a mineral remarkable for the complexity of its composition. It is thought that this must have a marked significance with respect to the genesis of the deposits. R. C. Wells, who made the analysis (p. 34) of this mineral, has supplied the following comment on the conditions of formation of tetrahedrite from aqueous solutions.

The conception that tetrahedrite forms from simple aqueous solutions is unsatisfactory for several reasons. In the first place, the sulphides are among the most insoluble compounds known in chemistry and tetrahedrite commonly contains lead and silver, whose sulphides are among the most insoluble of sulphides.¹ Secondly, it would be remarkable if such a process did not result in greater differentiation into single sulphides; for if the solutions were acid the precipitation of zinc and iron would be retarded, whereas if they were alkaline the deposition of antimony and arsenic would be prevented. In neutral solutions fractionation should still occur.² These are the behaviors under ordinary conditions, and it seems reasonable to suppose that they would persist to some extent even under high pressure, although by a mass effect of much hydrogen sulphide under pressure all the sulphides could probably be produced under any condition of acidity or alkalinity.

As a sulphide dissolving into pure water would be hydrolyzed into metallic hydroxide and hydrogen sulphide, it is obvious that a large excess of hydrogen sulphide would be required to prevent this hydrolysis and maintain a suitable concentration of sulphide in the solution to reprecipitate the sulphide at another point. Similarly, with the concentrations of metallic ions. It is conceivable that a particular concentration of copper and antimony, and of all the other bases as well as the sulphide, might be in equilibrium with tetrahedrite and by cooling deposit it from solution. For this to occur I should hazard the guess that the metals in solution would be in the following order, beginning with that of the highest concentration: Iron, zinc, arsenic, antimony, copper, silver. This guess is made upon the principle that the concentrations should be in inverse order to the solubilities. However, our knowledge of these matters, particularly about the conditions of the precipitation of compound sulphides, is so scant that further speculation might not even be suggestive.

The solvent usually assumed for carrying these sulphides is sodium or potassium sulphide. Becker³ showed that mercuric sulphide, pyrite, cupric sulphide, and zinc sulphide are soluble in differing degrees in sodium sulphide solution. He concluded, however, that "the sulphides of lead and silver seem to be entirely insoluble in sodic sulphide, sodic sulphhydrate, or in solutions of sodic carbonate partially saturated with sulphydric acid." He obtained no evidence of solution with these sulphides even when heated above 100° with reagents in closed tubes. As silver is an important constituent of the Bay Horse tetrahedrite, this would indicate that it was not carried in sodium sulphide solutions unless antimony, copper, or some soluble salts affect the solubility of the silver. I have been unable to find any marked solubility of silver sulphide in sodium sulphantimonite. Ditte⁴ has shown that silver sulphide in contact with potassium sulphide solution forms a very slightly soluble compound of red color, possibly of the composition $4\text{Ag}_2\text{S} \cdot \text{K}_2\text{S} \cdot 2\text{H}_2\text{O}$. This compound is decomposed by excess of water. A double salt with sodium sulphide was obtained by Ditte

¹ Weigel, O., *Zeitschr. physikal. Chemie*, vol. 58, 1907, p. 293.

² Wells, R. C., *Econ. Geology*, vol. 3, 1910, p. 6.

³ Becker, G. F., *Geology of the quicksilver deposits of the Pacific slope*: Mon. U. S. Geol. Survey, vol. 13, 1888, p. 430.

⁴ Ditte, A., *Chem. Rev.*, vol. 120, 1895, p. 91.

only at a high temperature from a saturated solution of sodium sulphide which at 110° contains about 800 grams of Na_2S . Its formula is given as $3\text{Ag}_2\text{S} \cdot \text{Na}_2\text{S} \cdot 2\text{H}_2\text{O}$. It is decomposed by excess of water.

Hence silver sulphide is soluble in concentrated potassium or sodium sulphide solutions but practically insoluble in dilute solutions of the alkalis.

In view of these facts it appears that the transfer of tetrahedrite could not be accomplished by dilute solutions of alkaline sulphides much more advantageously than by solutions of any other salts, although if the solutions were concentrated it might be carried.

Two factors which seem to have a bearing on the nature of the mineral-bearing solutions are, first, the development of sericite, a potash-rich mineral, in the walls, and second, the presence of an excess of sulphur in the tetrahedrite. This would seem to justify an opinion that potassium sulphide was a constituent of the mineralizing solutions, and from Wells's discussion of the chemistry involved that it was very possibly the solvent of the tetrahedrite.

The source of the solutions is even more difficult of determination than their nature. If potassium sulphide was the solvent it could have been efficient only at high temperatures, as indicated by Ditte's experiments ¹—temperatures probably greater than are normal at a depth of 8,000 feet. It has already been shown from geologic and physiographic evidence that the granite intrusions and the veins are closely related in age, and as special conditions of deposition are necessary to account for the deposits it seems altogether reasonable to assume a genetic relation between the two. Elsewhere in Idaho, notably in the Wood River district ² and in Lemhi County, ³ a genetic relation to an igneous mass of the same age is indicated by geographic distribution. Thus it is concluded that the silver-copper deposits are genetically related to an outlier of the great granitic batholith of Idaho. The nature of this relation, however, is not susceptible of demonstration. The magma may be thought (1) to have supplied the solutions or (2) to have stimulated the circulation of meteoric waters. The first view is favored by most economic geologists, but to distinguish between the alternatives is a problem on which individual deposits of this type throw but meager light.

LEAD-SILVER DEPOSITS.

DISTRIBUTION AND HISTORY.

Lead-silver deposits have been recognized in the Bay Horse and Loon Creek districts. In the Loon Creek district only two prospects have been opened on this type of ore and neither is extensive, but about Bay Horse and Clayton there are several mines noteworthy

¹ Op. cit.

² Lindgren, Waldemar, The gold and silver veins of Silver City, De Lamar, and other mining districts of Idaho: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 3, 1900, p. 217.

³ Umpleby, J. B., Geology and ore deposits of Lemhi County, Idaho: Bull. U. S. Geol. Survey No. 528, 1913, p. 51.

for their lead-silver production, important among which are the Red Bird, Excelsior, Beardsley, River View, Pacific, and Cinnabar properties.

The total production from deposits of this type within the area is about \$4,000,000, three-fifths of which has been derived from lead and the balance from silver. Since the general slump in local mining, which took place about 1900, the annual production has averaged perhaps \$15,000, derived largely from small shipments made by leasers operating on inadequately developed claims.

GEOLOGIC RELATIONS.

The deposits near Bay Horse are inclosed, without exception, in dolomitic limestone and dolomite, but the Red Bird deposit is in part inclosed in dolomitic limestone and in part in calcareous shales. One of the deposits near Ivers is within granite and the other within Algonkian schist, but both are in close proximity to areas of dolomitic limestone. Schist also is said to be the country rock at the Livingston property, near the head of Slate Creek. It is most striking, however, that the lead-silver deposits which have been important producers are all situated within or near areas of dolomitic limestone or dolomite.

Igneous rocks do not occur in their immediate vicinity, although both diorite and granite outcrop within a few miles of the principal mines.

CHARACTER OF THE DEPOSITS.

The lead-silver deposits are commonly tabular in general outline, but in their formation replacement processes have played an important though not a dominant part. Preexisting lines of parting have determined the general shape of the deposits. Thus they follow either fissures, as the Red Bird vein, or bedding planes, as the Pacific deposit, extensions from each being determined by fissures, joints, or bedding planes. In detail, however, some of the deposits are most irregular. In the Beardsley mine, for instance, bunches of ore isolated in the walls, save for narrow stringers connecting them with the main deposit, are common. These bunches of ore range from pieces the size of baseballs to masses 10 or 25 feet across. Also in old stopes, where the walls have been carefully stripped of ore, the surface is in many places exceedingly ragged and characterized by angular protuberances from a few inches to 3 or 4 feet in length, corresponding to which were embayments of ore into the country rock. In contrast to the deposits where such irregularities are common, the Red Bird vein is bounded by rather even walls.

Although all development has been well above the ground-water level of the region, yet in but few of the deposits is oxidation complete or even well advanced. The Red Bird ore is largely oxidized, but elsewhere the primary minerals predominate, most important among

them being argentiferous galena and siderite. This is true of all the deposits at Bay Horse, with the possible exception of the Beardsley and Excelsior, in which oxidation, though well advanced, is by no means complete.

THE ORES.

Ore shoots.—Pay shoots, in the strict sense of that term, are not common in the lead-silver deposits. The relative amount of ore and gangue is almost constant from place to place, so that when one gives out the other also is absent. Certain of the ore bodies have proved especially remunerative because of their persistence, and these have commonly been called shoots, important among them being the Potato Patch shoot of the Red Bird mine, and the main Beardsley-Excelsior ore body. The latter ranged from 100 to 200 feet in length and 1 to 20 feet in width; the former was 60 to 80 feet long and 20 to 30 feet wide.

Minerals of the ore.—Mineralogically, the lead-silver ores are simple, the essential primary minerals being argentiferous galena in a quartz-siderite gangue. Associated with the galena is a little tetrahedrite, sphalerite, pyrite, and chalcopyrite. Near the surface in all the deposits, and in the Red Bird mine throughout its known vertical extent of perhaps 900 feet, the ore consists of the oxidation products of these minerals.

The secondary ore is predominantly composed of sand carbonate heavily stained with the oxides of iron and manganese. The sulphate of lead, anglesite, is an intermediate product in the transformation of galena to cerusite, but, though very common, is abundant only locally in the Red Bird mine. Its usual occurrence is as a narrow and poorly defined band between the sulphide and carbonate, easily recognized by its dark color and adamantine luster, thus contrasting with the metallic luster of galena on the one side and with the lighter color of cerusite on the other. Smithsonite occurs as botryoidal surfaces of drusy appearance, lining cavities in the secondary ore. In many places columnar crystals of calamine protrude from such surfaces. Fluorite occurs locally in the Red Bird mine as small bluish-white cubes set on drusy surfaces of smithsonite. Manganese oxide is conspicuous in much of the secondary ore, but its primary equivalent was not recognized. Copper carbonates, though not abundant, are rather uniformly distributed. Iron oxide, derived largely from siderite and subordinately from pyrite and chalcopyrite, is everywhere present in the sand carbonate ores. Of the several elements found in the oxidized ores the mineralogic form of silver alone is doubtful. Minute grains of cerargyrite have been identified, but it can not be said that all the silver is in this form. Minium, the red oxide of lead was recognized in specimens from the Beardsley ore bins.

A general and probably fairly accurate idea of the composition of these ores may be had from the following smelter returns. The shipments represent roughly hand-sorted material, which, from the range in sulphur, evidently includes both primary and secondary minerals.

Average analyses of 13 shipments of ore from the McGregor group, Bay Horse, Custer County, Idaho.

	Au.	Ag.	Pb.	Cu.	Fe.	Zn.	S.	SiO ₂ .	Total shipped.
	Ounces.	Ounces.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Tons.
Average.....	0.041	69.90	57.34	1.76	1.29	2.59	4.92	21.17	553
Highest figure.....	.016	92.5	63.30	3.06	3.16	3.4	7.4	29.5	.....
Lowest figure.....	.075	44.7	47.85	1.80	.58	1.86	.91	15	.....

Tenor of the ore.—The lead-silver ores are of excellent grade, perhaps 40 to 60 per cent of lead and 60 to 80 ounces of silver to the ton being the tenor of those most commonly mined in this area. So generally and uniformly is the galena argentiferous that where it is present somewhat more than 1 ounce of silver for every per cent of lead may be assumed with fair safety.

The many problems connected with the alteration of this type of ore—the relative amounts of lead, silver, and zinc near the outcrop compared with the relative amounts below, and the value of the oxidized ore relative to the primary ore—can be elucidated but little as a result of these studies. When the district becomes active, however, it will be an excellent field for special studies on these problems.

AGE AND GENESIS.

The discussion of the age of the silver-copper veins (pp. 35–38) applies equally well to the lead-silver deposits. They are thought to have formed during the late Cretaceous or the early Eocene.

The genesis of the lead-silver deposits also is thought to be similar to that of the silver-copper veins. The two types have many important features in common. In each the formation of siderite characterized the earliest stage of mineralization. This was followed by quartz and the metallic sulphides and sulphantimonites. Both types are rich in silver; both contain lead and copper, although the vastly different amounts of these metals afford the basis for a fairly definite distinction. The Hoosier mine contains two parallel flat-lying veins 60 feet apart, which have the same geologic relations; both are followed by a thick vein of barren quartz, and indeed there is every geologic reason for thinking that they are absolutely contemporaneous in origin, yet one furnishes a distinct lead-silver ore and the other a distinct silver-copper ore.

Two eccentric occurrences which may have considerable genetic significance are related to this type of deposits, and although no

attempt is made to interpret them the facts are recorded in this connection. The peculiar veins of massive clear-white quartz, one 10 to 12 feet thick and the other 40 feet thick, which overlie both of the Hoosier veins, form one of these features. They are slightly later than the vein, and, as is suggested (p. 70), it is believed that they followed closely the opening of the spaces which they occupy, or perhaps caused them. The other special feature is the sharp transition of the Red Bird lead-silver ore body into an underlying mass of vuggy pyrite 50 or more feet across, at a point between the seventh and eighth levels of the mine, the only place where it has been cross-cut. (See p. 75.)

GOLD-COPPER DEPOSITS.

Deposits characterized by gold-copper ores are recognized only in the Loon Creek district, in the northwestern part of the area studied. Here but one mine, the Lost Packer, has been an important producer of this type of ore, although two or three similar veins are situated in its immediate vicinity.

GEOLOGIC RELATIONS.

The deposits are situated in a mountainous area in which elevations range from 5,000 to more than 9,500 feet. The topographic features are carved from rocks of Algonkian, Paleozoic, late Cretaceous, and early Tertiary ages. The Algonkian comprises mica schists and quartzites which outcrop over an irregular area of about 2 square miles, in the northern part of which the deposits are situated. West of the Algonkian area a vast extent of quartz diorite appears at the surface, and southwest of it outcrop the Paleozoic beds, which consist of quartzites, slates, and dolomitic limestones. A great number of granite, granite porphyry, and diorite porphyry dikes traverse the Algonkian rocks, and extrusions of quartz latite cap the Algonkian in its northern part.

In age the veins are intermediate between the granite and the numerous granite porphyry and diorite porphyry dikes.

CHARACTER OF THE DEPOSITS.

The gold-copper deposits occupy fissures which strike a few degrees east of north and dip about 75° NW. The Lost Packer fissure has been traced from Canyon Creek, at Ivers, north about 3,000 feet to the quartz latite above the mine. South of Canyon Creek it has not been definitely recognized, but several small outcrops may represent its continuation. This fissure has been explored for about 2,000 feet along its strike and 1,000 feet on its dip. It is bounded by well-defined walls which commonly stand 3 to 5 feet apart, the interim being filled with gouge, sheeted wall rock, or ore. The

walls present numerous slickensides, but distinct grooves having even an approximately uniform direction do not appear. The gouge also evidences much shearing and gliding between contiguous parts. Important displacement along this fissure, however, is not recorded. Most of the movement clearly antedates the ore and probably determined the channels along which the ore-bearing solutions traveled. In general, the vein material is confined to the fissure, though in a few places bunches of chalcopyrite have been found as far as 20 feet from the main ore bodies. Within the fissure, in most places the ore occurs as a definite band, ranging in width from a few inches to 3 or 4 feet and averaging perhaps 20 or 24 inches. It follows either the footwall or the hanging wall, perhaps being more commonly next to the former.

ORE SHOOTS.

The deposits are further characterized by ore shoots, which lie in the plane of the vein at irregular intervals along its strike. In the Lost Packer mine three are recognized. Intermediate between the shoots the walls are much closer together than elsewhere, although the position of the fissure is always indicated by a band of gouge from 1 inch to 3 or 4 feet thick. The shoots are unequally spaced, but all pitch to the south, thus presenting a decided parallelism (fig. 4, p. 95). The position of these shoots is thought to have been determined by relative movement of the walls sufficient to bring reversed curves opposite each other. This opinion is based on two observations: First, although in any cross section in a shoot both ore and gouge are commonly present, it seems to be true that where the walls are farthest apart the ore is widest, and also that the walls are farther apart within the shoots than at points intermediate between them. Second, the general parallelism of the shoots suggests this origin.

THE ORES.

General character.—The gold-copper ore is essentially auriferous chalcopyrite in a siderite-quartz gangue, the relative importance of the three minerals varying markedly from place to place in the same shoot and especially in the different shoots. The amount of gold associated with the chalcopyrite is exceptionally large, assays of this mineral commonly showing 2 to 3 ounces of gold to the ton. Inter-grown with the siderite of the gangue is a little calcite. Pyrite is exceedingly rare, but locally occurs as small grains and cubes within the chalcopyrite. Similar in its occurrence is pyrrhotite, but it is even less abundant. A little barite has been reported by Jennings,¹ but careful search during the present studies failed to reveal this mineral.

¹ Jennings, E. P., The Lost Packer copper-gold lode (Idaho): Jour. Canadian Min. Inst., vol. 9, 1906, p. 55.

Oxidation products are not quantitatively important in the deposits and disappear entirely within 50 or 75 feet from the surface. Most important among them are oxides of iron and carbonates of copper. Films of bornite and a few of native copper occur locally a few feet beneath the surface.

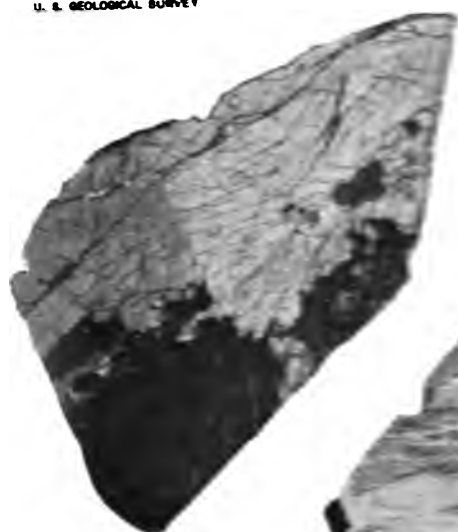
Mineralogy of the different shoots.—The three shoots of the Lost Packer mine, the only developed deposit of this type, contain ores rather distinct from each other in mineralogic composition. The shoots are locally designated the north, south, and middle. Ore from the north shoot consists of coarse-textured milky to bluish white quartz with much chalcopyrite and a little pyrrhotite irregularly scattered through it. On most levels siderite is rare, but on No. 4 it is equally abundant with chalcopyrite and presents the same irregular distribution. The middle shoot, the most productive in the mine, contains ore which consists essentially of chalcopyrite and distributed as bunches, small patches, irregular grains, and interstitial fillings in a gangue of coarse white quartz. Here chalcopyrite constitutes about one-third of the total material mined. Siderite is present but is never an important constituent. The south shoot contrasts with the other two in that siderite is its most abundant mineral. Chalcopyrite is associated with the siderite in such proportions that the ore runs 26 per cent iron and $4\frac{1}{2}$ per cent copper. (See Pl. VIII, A.)

Gold is included about equally in the quartz and the chalcopyrite, each containing 2 to 3 ounces to the ton, but less is present in the siderite, assays of this mineral commonly showing about half an ounce to the ton.

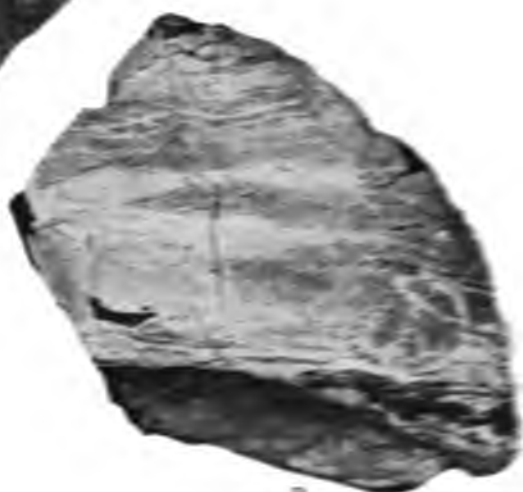
Tenor of the ore.—The ore which has supplied the total production of about half a million dollars, has averaged between \$80 and \$90 to the ton, but for every ton of this grade which has been encountered in the deposit there is estimated to be $2\frac{1}{2}$ tons which will average \$25.

AGE AND GENESIS.

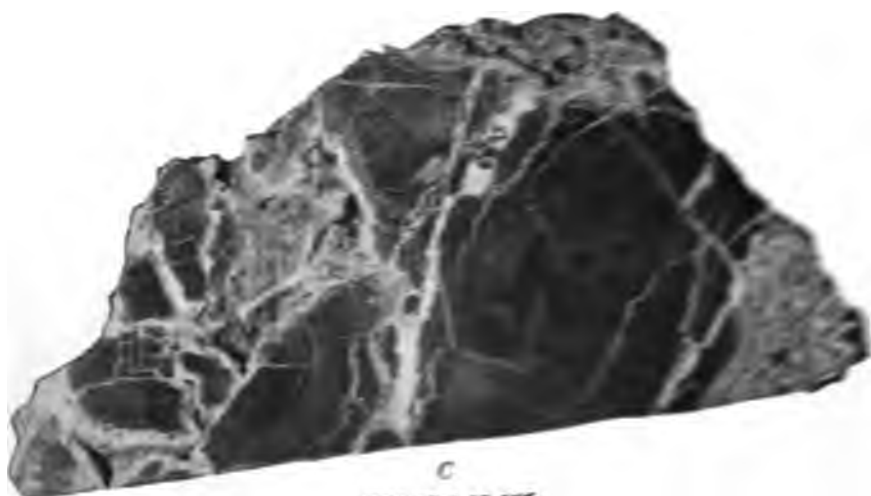
The gold-copper veins outcrop through a vertical range of about 1,600 feet, the highest exposure being but little below the level of the Eocene erosion surface. Within this distance there is no mineralogic change which seems in any way related to depth of deposition. In the deposit, however, are appreciable quantities of pyrrhotite, a mineral believed to indicate deposition at considerable depth—a depth probably exceeding 3,000 or 4,000 feet. It is believed, therefore, that the veins were formed well before the close of the Eocene. On the other hand, the Lost Packer vein cuts across granite dikes which are evidently a phase of the quartz diorite intrusion. Thus the veins are post-quartz diorite. It has been shown (p. 23) that this igneous mass was very probably intruded at about the close of the Cretaceous.



A



B



C

SPECIMENS OF THE

- A. Chalcopyrite (dark, irregularly shaped, crystalline, with a lighter, textured area on the right side) in the siderite. Darker areas on the right side of the specimen are chalcopyrite. No. 7 level. Huron Co.
- B. Sheared galena (dark, irregularly shaped, crystalline, with a lighter, textured area on the right side) was brought out by crushing for 24 hours in a mortar and pestle. No. 7 level. Huron Co.

These veins are therefore believed to have formed during the early part of the great period of erosion which resulted in an Eocene surface of gentle topographic forms (p. 28). Further evidence that they were formed during the early part of this period is afforded by their relation to the granite and granite porphyry dikes. These dike rocks are probably very closely related in age, yet the veins are older than the one and younger than the other.

The genesis of the deposits is not apparent from local evidence, although their close accordance in age with the quartz diorite batholith strongly suggests a genetic relation between the two. Considered broadly, the most significant fact relative to the genesis of ore deposits in general is the almost universal presence of igneous rocks near them. The metallic constituents of some types, such as contact-metamorphic replacement deposits and segregated ores, have been unquestionably derived from the inclosing or near-by igneous rock. Gradations exist between these types and veins, and hence in studies of small areas it is not inappropriate to revert to broad correlations for evidence on genesis.

Granitic rock, one phase of which is represented by the quartz diorite near Ivers, outcrops continuously over more than 20,000 square miles in central Idaho. Surrounding this area are numerous batholiths, reasonably supposed to be outliers. Igneous intrusions, therefore, which must have created very exceptional physical and chemical conditions at about the time the ores were deposited, are present. In places in adjoining regions comparable deposits are definitely distributed along the margins of such intrusions. Thus the deposits at Wood River occur along the borders of a central granitic mass,¹ and those in the Mackinaw district, Lemhi County, are similarly situated.²

From the above considerations it is concluded that the quartz diorite intrusion is the direct cause of the formation of the gold-copper veins, and it is believed that it supplied most of their constituents.

POST-OLIGOCENE ORE DEPOSITS.

GOLD-SILVER VEINS.

Veins characterized by gold-silver ores have been found only in the Yankee Fork district, but here they are rather widely distributed. Custer, Bonanza, and Sunbeam have each in the past been centers of important mining operations. The total production of the gold-silver veins is estimated at \$12,000,000, about 40 per cent of which has been in gold and the remainder in silver.

¹ Lindgren, Waldemar, The gold and silver veins of Silver City, De Lamar, and other mining districts in Idaho: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 3, 1900, pp. 190-230.

² Umpleby, J. B., Geology and ore deposits of Lemhi County, Idaho: Bull. U. S. Geol. Survey No. 528, 1913, p. 152.

GEOLOGIC RELATIONS.

The rock formations in the vicinity of the gold-silver veins include Algonkian schists and quartzites, and Miocene tuffs, latites, andesites, basalts, and rhyolites. The Miocene rocks occupy a great erosion valley about 10 miles wide and 3,000 feet deep, which was developed after the elevation of the Eocene erosion surface. The gold-silver veins are wholly inclosed in these rocks.

METASOMATIC ALTERATION OF THE WALL ROCKS.

Intense metasomatic alteration of the wall rocks adjacent to the fissures is a conspicuous feature of the gold-silver veins. Silicification or sericitization, or both, characterize the rocks for 50 or 100 feet, and in many places for 1,000 feet or more from the deposits. The silicification is most intense next to the veins and gradually gives way to sericitization at a distance of 50 or 100 feet. Well removed from the veins, say beyond 200 feet, chlorite is locally an abundant metasomatic mineral. So intense is this alteration that in many of the thin sections it is impossible to determine whether the original rock was a tuff, andesite, or rhyolite. Where better preserved the rhyolites show phenocrysts of quartz and partly altered orthoclase in a highly sericitized or silicified groundmass. In the andesites and latites the phenocrysts and groundmass seem to have altered with about equal facility. Small cubes and patches of pyrite are abundant in most of the wall rock near the veins. For more detailed descriptions see page 83.

CHARACTER OF THE VEINS.

The ore bodies commonly occur as veins about 4 feet wide, but in the Golden Sunbeam mine the principal body was a great irregular mass of mineralized tuff, which on No. 2 level was 130 feet long by 75 feet wide and extended upward 85 feet and downward 115 feet. The Montana shoot also was of exceptional shape, being 20 to 25 feet in length by 5 to 17 feet in width and 530 feet in depth. In general, the contact of the vein material with the inclosing rock is sharp and the numerous included fragments of wall rock are angular. A pronounced banding is conspicuous in the veins; the bands broadly parallel the walls, but in detail concentric arrangement is common.

The vein filling is predominantly fine-grained quartz, and associated with it are small amounts of chalcidony and opal. Calcite is conspicuous in some of the deposits, as in the Lucky Boy, where it constitutes perhaps 20 per cent of the vein. The calcite occurs both as equidimensional rhombohedral crystals and as lamellar crystals, the latter commonly replaced by quartz. Indeed, much of the quartz has this lamellar form, showing it to be pseudomorphous after calcite. Adularia is locally either intergrown with or embedded in the quartz.

The metallic minerals are irregularly distributed through the quartz and, to a less extent, through the calcite. Dark-gray bands of sub-metallic luster parallel the crustification of the vein material in many places. Within these bands individual minerals are too small for identification even with a microscope. Along the strike of the veins the ore minerals are largely confined to definite sections, thus forming the ore shoots, which alone have been mined at a profit.

ORE SHOOTS.

The ore shoots of these deposits comprise (1) segments of otherwise comparatively barren quartz-calcite veins, (2) disseminations of stock-like form not related to fissure fillings, and (3) chimneys of ore apparently independent of fissure veins. The most important deposits are of the first type, which represents all the mines except the Golden Sunbeam and the Montana. The Golden Sunbeam was a great stock-like body of mineralized tuff, and the Montana was a chimney of ore about 10 by 20 feet in cross section.

THE ORES.

Mineralogy.—The unaltered ore is a fine-grained quartz, locally accompanied by large amounts of calcite and a little chalcedony, opal, and adularia. Of the metallic sulphides pyrite alone is abundant and uniformly present. Tetrahedrite is not uncommon, and chalcopryite, galena, and rarely enargite occur in some of the deposits. Widespread and important, as they have been found to characterize the richer ores, are blue-black submetallic bands and blotches, in which pyrite and gray copper and rarely chalcopryite may be recognized with the aid of the microscope, but the predominant material shows as blue-black specks too small to be identified. Partial analyses of two specimens of this material were made by R. C. Wells. A specimen from the Montana mine showed gold, selenium, lead, a little bismuth, and a trace of copper. Tellurium was not present. A specimen from the Lucky Boy dump contained gold, selenium, lead, some copper, and a trace of bismuth. Here also tellurium was not detected. The definite amount of selenium in both of these ores, the only ones analyzed for it, suggests the presence of some selenide.

An analysis of Lucky Boy ore taken at a depth of about 400 feet from the surface was furnished by Mr. Nicholas Treweek, manager of the Lucky Boy Gold Mining Co., and is as follows:

Partial analysis of ore from Lucky Boy mine, Custer County, Idaho.

[Analysis by Union Assay Office. Gold and silver in ounces per ton; other items in percentages.]

Gold.....	1. 34
Silver.....	25. 90
Lead.....	. 00
Copper.....	. 00
Insoluble.....	67. 30
Zinc.....	. 00
Sulphur.....	. 50
Iron.....	1. 40
Lime.....	15. 40

By calculating the calcium oxide as calcite, and adding to this the amounts of other constituents shown in the analysis, it is readily seen that about 3 per cent of material is not accounted for. Some of this material is doubtless moisture, but it probably also represents the several constituents identified by Mr. Wells (cited above).

The oxidized ore is firm quartz, heavily stained with iron, manganese, and locally with copper. Calcite is rare in the outcrops, but numerous lamellar and rhombohedral forms of quartz indicate its former presence. Kaolin of creamy white color, unless stained by iron oxide, occurs in cavities and along crevices in the oxidized ore. It is probably in part due to the weathering of adularia, and in part is infiltrated from the sericite and feldspar of the wall rocks. Cerargyrite and wire silver are both present, but only locally do they occur in noteworthy quantities. Much of the gold even in the primary ore is free, though so minutely divided as to be invisible even microscopically. Coarse gold occurs near the surface in some of the deposits, notably the Morrison vein. Some of the gold may be associated with the selenium as a selenide, though the relation, if it exists, has not proved susceptible of demonstration with the material at hand.

Tenor of the ores.—Gold and silver are present in quantities which vary from place to place. Thus the Montana shoot furnished predominantly gold ores, whereas the General Custer contained only 1 ounce of gold to 80 or 90 ounces of silver. In general, the ores mined have been high grade, common assays ranging from \$50 to \$100 per ton, some of them much more.

It has been generally found in the area that the tenor of the ores decreases markedly with depth. The Montana shoot was worked at big profit for the first 500 feet, but a tunnel driven to tap it at greater depth failed to reveal ore in commercial quantities. The General Custer ore body was not worked below the level of Yankee Fork.

The Golden Sunbeam was disappointing on the lower levels. The Charles Dickens was abandoned at a depth of 250 feet, as was also the Morrison. The Lucky Boy, the deepest mine in the district, was worked to the 900-foot level, but most of the production came from much nearer the surface.

An analysis of the problem, however, indicates that for the veins as a whole this impoverishment may be more apparent than real. In the first place, the ores below a depth of 50 to 100 feet are primary; second, they were formed before erosion had carved most of the present topographic features; and, third, they occur at various elevations between 6,500 and 9,500 feet. Otherwise stated, primary ore plays out at a moderate depth below an accidental surface of erosion which is far from parallel to the surface prevailing at the time of ore deposition. Thus it can not be assumed that depth below the original surface determined the lower limit of the deposits as now known. From this line of evidence it would seem that though the shoots now known have given out at moderate depth, others like them in shape may be present well below the now existing accidental surface. Opposed to such a conclusion, however, is the fact that with a few exceptions veins of this type and age have not been worked at a profit below 1,000 feet, and the greater part of their aggregate production has come from a depth less than 500 feet.

AGE AND GENESIS.

The gold-silver veins are inclosed in lavas of Miocene age. After their formation great valleys were carved and as these valleys are partly filled with outwash from the ice they evidently existed at the beginning of the Pleistocene. Some of them, as that of Yankee Fork, are more than 3,000 feet deep, and because they occur near the headwaters of the stream which drains the area it does not seem unreasonable to assign most of the Pliocene epoch to their development. As the veins existed before the valleys were formed, and as they are inclosed in Miocene rocks, the ore deposits are believed to be of late Miocene or early Pliocene age.

In a study of the genesis of these deposits three principal features stand out—(1) the intense and far-reaching alterations of the wall rock, (2) the angular form of wall-rock fragments inclosed in the veins, and (3) the general crustified arrangement of the vein material. The composition of the veins themselves is important but seems to have less bearing on the problem of genesis. Intense alteration of the wall rock appears in every specimen studied—near the veins silicification, farther removed sericitization, and locally also chloritization. Solutions thus capable of working out into the walls were probably highly heated and impelled by considerable pressure.

They did not, however, possess corroding properties to any marked degree, for included fragments of wall rock are notably angular. Further, the solutions operated in open channels, as shown by the general crustification of the vein material and the numerous cavities lined with druses of quartz crystals.

It has been shown above that the veins are closely related in age to the lavas and tuffs which inclose them. They also present the type of wall-rock alteration which in many districts where detailed studies have been made has been attributed to hot ascending solutions genetically related to some igneous activity. It is believed, therefore, that the gold-silver veins of Yankee Fork district are genetically related to the same igneous activity which earlier found expression in the great beds of tuffs and lavas.

GOLD PLACERS.

Distribution and history.—Gold placers are recognized in the Loon Creek and Yankee Fork districts. The first discovery was made near the mouth of Canyon Creek, a tributary of Loon Creek, in 1869 and during the decade following the placers were actively worked, producing upward of \$1,000,000. During the period of placer activity on Loon Creek gold was discovered in the gravels along Jordan Creek in the Yankee Fork district. Here the production was not large, probably not more than \$50,000.

Character of the deposits.—Placer locations along Yankee Fork cover the valley flat from Salmon River to Jordan Creek, and thence extend up the latter stream for about 2 miles. Extensive exploration by drilling has been accomplished, but with what success is not generally known. The early production came from the area near the mouth of Jordan Creek, where the gold occurred as fine flakes and a few large nuggets that were found near bedrock. Here the gravel bed was thin, but south of this place it is known to be as much as 90 feet thick.

On Loon Creek 470 acres are held as placer ground by the Loon Creek Hydraulic Placer Co. The area is $4\frac{1}{2}$ miles long and about 1,000 feet in average width. A strip 75 feet wide and about 1 mile long situated along the upper part of the main channel, afforded the early production. Here the gravel bed is 2 to 6 feet thick, but back of it are terraces 10 to 30 feet high, which the present owners have prospected during two seasons and are now planning to hydraulic. The average return from the numerous prospect pits in these terraces was about 25 cents a cubic yard.

The Loon Creek placers comprise loosely cemented auriferous gravels which rest upon a rather even floor of schist. The pebbles average perhaps 3 inches in diameter, though locally boulders as

much as 3 feet and a few 6 feet across are encountered. Sand is the cementing material. The gold occurs in the lower 2 or 3 feet of the deposits and in joints and shallow depressions in bedrock. Coarse gold prevails, nuggets weighing an ounce or more being not uncommon, and perhaps 50 per cent of the product averaging 25 cents a color or more. Its market value is \$18 per ounce.

Source of the placer gold.—The gold of the Yankee Fork placers is obviously derived from the late Tertiary veins, above which it does not extend. Most of the production came from that portion of Jordan Creek immediately below its intersection with the Morrison-Charles Dickens vein—a relation which points to that vein as the source of most of the gold heretofore mined.

The Loon Creek Placer gold is thought to have come from the late Cretaceous or early Eocene veins which cross Canyon Creek, for the following reasons: First, placers have not been found above the mouth of Canyon Creek, and, second, the amount of gold diminishes abruptly with increasing distance below its junction with Loon Creek.

It is noteworthy that, although the older veins themselves have not been nearly as productive as the younger ones, the placers derived from them have been vastly more productive—a relation in keeping with the widely made observation that the late Tertiary veins do not yield extensive placers even though they are not uncommonly bonanza deposits.

Age of the placers.—The placers are believed to have formed late in the Pleistocene epoch. The great gravel beds, which in part are auriferous, occupy post-Miocene erosion valleys. Their accumulation in such valleys indicates a change from conditions of erosion to those of deposition. This may most reasonably be thought to have occurred during the general period of ice recession. At this time there was an abundant supply of running water and a proportionately greater supply of rock rubble loosened and in part ground up by the glaciers. As the ice front retreated up the precipitous tributary canyons, vast amounts of material would continually be made available for transportation, and the streams, if fully loaded in their upper, swifter parts, would necessarily deposit below, where the grade was lower.

It is therefore believed that the auriferous gravels were deposited late in Pleistocene time—a belief which is supported by the small amount of erosion which they have undergone.

MINERALS OF THE DEPOSITS.

At least 32 mineral species occur in the deposits of the three districts herein described. These include 7 gangue minerals and 8 primary and 17 secondary metallic minerals. Of the several species

chalcopyrite, galena, tetrahedrite, and quartz (auriferous) are individually important as ores. The minerals are listed in alphabetical order below, together with brief notes on their occurrence.

Adularia.—Vein feldspar is common though not abundant in the late Tertiary veins of the Yankee Fork district. It is usually of microscopic size and occurs either intergrown with the quartz or included in it.

Anglesite.—Lead sulphate occurs in all the lead-silver deposits of the area. It represents an intermediate stage in the alteration of lead sulphide to lead carbonate.

Argentite.—Silver glance is rather abundant in many of the silver-rich oxidized ores of the late Tertiary veins.

Arsenopyrite.—The iron sulpharsenide is a primary mineral of minor importance in the silver-copper deposits of the Bay Horse district.

Azurite.—This carbonate of copper appears in many of the vein outcrops of the area but is nowhere sufficiently abundant to constitute an ore.

Barite.—Barite has been reported from the Lost Packer vein, but none was seen during the present investigation.

Calamine.—Zinc silicate occurs as bundles of clear white columnar crystals protruding from the walls of small cavities in the oxidized lead-silver ores.

Calcite.—Calcite is a common gangue mineral in the late Tertiary veins, in one of them, the Lucky Boy, constituting about 20 per cent of the ore.

Cerargyrite.—Silver chloride, though little of it is susceptible of identification, is probably the most abundant silver mineral in the oxidized lead-silver ores.

Cerussite.—Sand carbonate is the most important ore of lead that has been mined in the area. It occurs as granular masses, as a rule heavily stained with oxides of iron and manganese.

Chalcocite.—Copper glance is found locally as films along cracks in the upper level of the Lost Packer mine. It is probable that it was also present in the upper levels of the silver-copper deposits.

Chalcopyrite.—Chalcopyrite is the principal ore mineral at the Lost Packer mine, where it carries $2\frac{1}{2}$ to 3 ounces of gold per ton. It occurs in small amounts in most of the other deposits of the area.

Dolomite.—Dolomite occurs rarely as a gangue mineral in the lead-silver deposits.

Enargite.—Enargite was found in a few specimens of ore from Dickens Hill, Yankee Fork district.

Fluorite.—Small cubes of fluorite occur in cavities in the oxidized ore of the Red Bird mine, Bay Horse district.

Galena.—Argentiferous galena constitutes the chief primary ore mineral in the lead-silver deposits. It also occurs sparingly in the silver-copper deposits.

Gold.—Native gold is found in placers in the Yankee Fork and Loon Creek districts. It also occurs in the oxidized gold-copper ores, and in both the primary and secondary gold-silver ores.

Hematite.—Ferric oxide is widespread in the deposits of the area as an oxidation product.

Limonite.—Ferric hydroxide is similar in distribution to hematite.

Malachite.—Green copper carbonate is common as a stain in the outcrops of the gold-copper and silver-copper deposits.

Minium.—Lead oxide was seen in one specimen of ore from the Beardsley ore bins.

Pyrite.—Pyrite is a persistent mineral in the area, occurring in all the deposits. In the wall rock of the late Tertiary veins abundant small cubes of it accompany the metasomatic alteration.

Pyrolusite.—Dendritic manganese oxide is not uncommon along fractures in the lead-silver deposits.

Pyrrhotite.—This sulphide of iron was seen only in the ores of the Lost Packer mine, where it occurs sparsely as small crystals inclosed either in chalcopyrite or in quartz.

Quartz.—Quartz is a common gangue mineral in all the deposits, but is the predominant constituent only in the late Tertiary veins.

Siderite.—Iron carbonate is the characteristic gangue mineral in the pre-Oligocene deposits.

Silver.—Native silver occurs sparingly as twisted wirelike filaments in cavities in the late Tertiary oxidized ore.

Smithsonite.—Zinc carbonate occurs as botryoidal forms with drusy crystal surfaces lining cavities in the oxidized lead-silver ores.

Sphalerite.—Sphalerite is common in the primary lead-silver ore and occurs sparingly in the silver-copper ores. A few crystals also appear in the late Tertiary veins.

Tetrahedrite.—Tetrahedrite is the characteristic ore mineral in the silver-copper veins.

Wad.—An earthy mixture of metallic oxides in which manganese oxide is the dominant constituent is abundant in the upper portions of the lead-silver deposits. It may best be classed as wad.

OXIDATION AND GROUND-WATER LEVEL.

The extent to which oxidation has affected the ore deposits of north-western Custer County varies markedly in different parts of the area and in different deposits in the same district. In general, the gold-silver deposits are comparatively little oxidized below a depth of 40 or 50 feet. In the gold-copper veins oxidation is even less extensive, but

in the lead-silver and silver-copper deposits probably most of the ore which has been mined has been largely oxidized.

The difference in extent of oxidation is due to a number of factors, most important among them the amount of postmineral fracturing. The gold-copper veins are not only comparatively unfractured but are crossed by flat-lying, unjointed dikes, which protect the underlying portions of the ore body. Lack of fracturing also is the dominant factor in preserving the primary minerals of the late Tertiary veins. The deposits of Bay Horse district, on the other hand, are rather extensively fractured, but even here the extent of oxidation is erratic. In the Red Bird mine sand carbonate is conspicuous in the ore of the lowest workings, about 900 feet below the surface, although galena also is abundant. In the Pacific mine, however, with less than 200 feet of cover, galena predominates. The River View ore, as seen on the dump, is largely galena, though the mine is situated well up on a cliff of intricately jointed limestone. The silver-copper deposits, with the exception of the New Silver Bell, present primary ore throughout those portions of the workings now safely accessible.

If permanent ground-water level for the region be assumed to accord approximately with the bottoms of the numerous canyons, nearly all the mining development has been well above ground-water level. As in this area, where the beds are in general steeply inclined and joints and slaty cleavage are abundant, there seems no reason to doubt the above assumption, it is concluded that in the general erosion of the region oxidation has not kept pace with the general lowering of the water table.

FUTURE OF MINING IN NORTHWESTERN CUSTER COUNTY.

Northwestern Custer County is certain to produce important amounts of silver, lead, copper, and gold in the future, if only from deposits now developed. The deposits of the Bay Horse district are by no means exhausted, and in some a considerable tonnage is actually blocked out. Many others are inadequately developed and much of the intermediate territory is comparatively unprospected. In the Yankee Fork district little ore is in sight, and any important future production from the shoots now recognized is problematic, but in a heavily timbered area where such bonanza deposits have been found there is ever the probability of new discoveries. The Loon Creek district contains gold placers which will probably be worked in the near future. In addition to these are gold-copper veins, one of which has been explored to a depth of 1,000 feet and throughout the ore has varied in value from \$25 to \$90 to the ton with no evidence of impoverishment with depth. The area of dolomitic limestone near the head of Deer Creek is also thought to be a promising field in which to prospect for lead-silver deposits.

It is highly probable that in a rough country like northwestern Custer County new deposits will be found when mining again becomes active. Whether such activity will precede the advent of a railroad is doubtful, for the larger properties are held by companies which for many years have shown no inclination to rob the known deposits. The advent of a railroad, however, would doubtless inaugurate a mining activity of considerable importance.

The area is one far more worthy the attention of the prospector than many which are being more adequately explored. Few silver-lead deposits show prominently at the surface not only because they are slightly less resistant than the inclosing rocks but because the oxidation products, cerargyrite and sand carbonate, are earthy in appearance and commonly break up into small fragments. The absence of a quartz gangue implies the absence of the iron-stained quartz float, which has led the prospector to most deposits of ore. The silver-copper and gold-copper deposits, in that copper stains accompany their outcrops, are more readily recognized, and it is probable that fewer of them have been overlooked. The gold-silver veins outcrop fairly distinctly at the surface and their iron-stained float lessens the probabilities of new discoveries. New discoveries of any of the types of deposits, however, are to be expected, for most of the area is well timbered and many of the upper slopes are covered by a mantle of drift.

MINING DISTRICTS.

BAY HORSE DISTRICT.

SITUATION AND EXTENT.

The Bay Horse district, situated in the west-central part of Custer County, Idaho, comprises the area about that great bend in Salmon River where it changes from an easterly to a northerly course. Challis, the county seat of Custer County, is near its northern border, and the old mining town of Clayton is centrally situated within it. About midway between Challis and Clayton is Bay Horse, once a flourishing settlement of several hundred inhabitants, which now has dwindled to 7 or 8 persons, as most of the properties are held by three companies.

Excellent roads connect the principal settlements, and a daily (except Sunday) stage runs both up Salmon River to Yankee Fork district and down the Salmon to Challis. Mackay, reached from Clayton by way of East Fork and from Bay Horse and Challis by a more northerly route, is about 60 miles southeast and is the principal supply point.

The district is unorganized and of very indefinite extent. From the Livingston group in the southern part to the Dougherty claims in the north - ice of about 30 miles. Its average width is perhaps

. HISTORY.

The first location in the Bay Horse district was made in March, 1877, when the River View deposit was staked. In August of the same year the Ramshorn, Beardsley, and Excelsior were located. Active development began in 1880, and from then until 1898 the district supported an important mining industry. Two smelters, each of 60 tons daily capacity, are situated in the district, one at Bay Horse the other at Clayton. Both commenced operations in 1880 and operated four to five months each year until 1897, when the Bay Horse plant was permanently closed and later dismantled. Operation of the other plant continued until 1902, when it also was closed. In 1896 a mill was built at Bay Horse for concentrating the low-grade lead-silver ores encountered in the deeper workings of the Beardsley mine but was operated only a short time.

Since the smelters and mill were closed some of the mines have continued to produce a small amount each year, the ore at first being hauled 165 miles to Blackfoot, and after the fall of 1901 60 miles to Mackay. This annual output, larger at first, has averaged about two cars of ore, derived largely from development work.

During the period of activity three principal companies operated in the district—the Ramshorn Mining Co., the Clayton Mining & Smelting Co., and the Beardsley Mining Co. The Beardsley mines, however, early passed into the possession of the Ramshorn Co. Recently a large group, known as the James McGregor group, has been formed and now includes most of the smaller properties. The properties of the Clayton Co. are situated on Squaw Creek, near Clayton, and in Bay Horse Canyon (Skylark and Hood mines); the holdings of the other companies are near Bay Horse.

PRODUCTION.

Only a rough estimate of the total production of the district is possible. Much ore has been shipped in small lots and the early production is not definitely known. The total of the estimates given by local residents and the State mine inspector for the several properties indicates a production for the district of approximately \$10,000,000. This has been derived from three metals about as follows: \$6,900,000 from silver, \$2,700,000 from lead, and \$650,000 from copper. The silver was associated with the lead as argentiferous galena and its oxidation products, and with the copper as tetrahedrite and minerals derived from it. Of the productive mines the Ramshorn, Skylark, and Silver Bell, producing silver-copper ores, and the Red Bird, Beardsley-Excelsior, and River View, producing lead-silver ores, have been by far the most important.

MINING CONDITIONS.

The Bay Horse district is a well-timbered, well-watered area of bold topographic forms. It is a region of widely diverse climatic conditions due to its great ranges in elevation, but the principal roads are open to traffic throughout the year, and communication with outside supply points is easily carried on, even during the winter months. Salmon River and its tributaries present water-power sites suitable for the development of far more power than will ever be needed by local industries. The bold topographic forms encourage mining by tunnels in many places to depths of 2,000 feet or more.

Exclusive of transportation facilities, conditions affecting mining are far better than in most western camps. Under existing conditions a freight and treatment charge of \$20 to \$25 must be met by every ton of ore which is hauled the 60 miles to Mackay and thence shipped to the smelters at Salt Lake; the local treatment rate, including the consequent haulage of coke and bullion, was but little less. Much of the ore in the district could meet this charge and allow a good margin of profit, but to rob the deposits of their better ores has not been the policy of the companies which own the larger mines. As the district is traversed by the valley of Salmon River, a natural railroad route, and separated from Mackay by an exceptionally low divide, it would seem that the companies are justified in awaiting and expecting better transportation facilities.

At the time of the writer's visit the district was inactive, but in the spring of 1912 the properties of the Clayton Mining & Smelting Co. were purchased by the Idaho Smelting & Mining Co., and early in the fall the smelter at Clayton was blown in.

TOPOGRAPHY.

The Bay Horse district is a portion of an old plateau now deeply dissected by the streams which drain it. The largest of these is Salmon River, which flows in a deep, narrow canyon whose walls rise abruptly from its water line at an elevation of 5,000 to 5,500 feet by precipitous slopes to 9,000 or 9,800 feet above the sea and there open out into summit tracts remarkable for their accordance in elevation. The best-preserved remnant of the old plateau surface which these summits record is Poverty Flat, an area of about 25 square miles near Clayton. It stands 9,600 feet above sea and clearly bespeaks a former erosion surface which once stood near the base level of erosion for the region. This old erosion surface was developed during the Eocene epoch (see p. 17) and constitutes the most valuable local datum plane for that part of geologic time between the Paleozoic and the late Tertiary.

Salmon River is a rapidly flowing stream which heads about 50 miles west of the district. Within the district East Fork constitutes its principal tributary, although Slate, French, and Spudd creeks from the southeast, and Thompson, Squaw, Kinnikinnick, and Bay Horse creeks from the northwest add greatly to its volume.

GEOLOGY.

The most widespread rocks in the Bay Horse district are dolomites, dolomitic limestones, slates, and quartzites of Paleozoic age. In the southwestern part Algonkian metamorphic rocks are present, and in the eastern and northeastern parts are Miocene lacustrine deposits. Andesites and tuffs are intimately associated with the lake beds, and locally intruded into the older rocks are masses of late Cretaceous or early Eocene granite and diorite.

The Algonkian rocks, composed of slates, schists, and quartzites, outcrop along Salmon River from a point near the mouth of Thompson Creek westward for about 6 miles. The Livingston deposits are possibly inclosed in rocks of this age, but all the others are within Paleozoic beds. The Paleozoic section is perhaps best exposed in the north wall of Bay Horse Canyon and in the sides of Salmon Canyon near Clayton. It comprises about 9,000 feet of beds, consisting of massive quartzite overlain by dolomite, dolomitic limestones, and shales, and these followed by a great thickness of shales and slates. The section is discussed in some detail in another part of the report (p. 19) and need not be further described here.

Igneous rocks of late Cretaceous or early Eocene age comprise three areas; two of diorite and one of granite. One diorite mass outcrops for three-fourths of a mile in Kinnikinnick Canyon $2\frac{1}{4}$ miles north of Clayton; the other is of comparable size and is cut across by Salmon River 2 miles east of Clayton. The granite crosses the upper end of Bay Horse Canyon as a belt about a mile wide. Contact metamorphism due to the diorite was not noted, but adjacent to the granite the slates present an abundant development of andalusite (?) and muscovite, together with a few crystals of zoisite, actinolite, garnet, and tourmaline.

The lake beds and associated eruptive rocks and tuffs have no direct bearing on the ore deposits and will not be discussed here. A description of them appears on pages 26-27.

Structurally the dominant features of the district are north-south anticlines, one of which, traversed by Bay Horse Canyon, is about 3 miles across and on its limbs the beds dip 30° to 60° . From Bay Horse it plunges northward and within 2 miles the flat-lying beds constituting its crest descend to the bottom of Beardsley Gulch on a dip of about 25° . The structure of this anticline south of Bay Horse is not known. Between East Fork and Squaw Creek are two anti-

clines separated by a syncline which is followed by Kinnikinnick Canyon. Common dips on the limbs of these are 40° and 50° .

Faults are not conspicuous in the district, although the hurried nature of the examination makes it possible that important dislocations were overlooked. Probably the largest fault noted passes northwest-southeast a short distance above Bay Horse. It has a throw sufficient to bring the overlying (?) shales against the limestone which outcrops near the bottom of the canyon above Bay Horse—a throw which is probably hundreds of feet. In the Ramshorn mine two north-south faults with downthrow of 20 to 30 feet on the east were noted, and in the Skylark mine an east-west fault displaces the vein about 50 feet to the east on the north side.

ORE DEPOSITS.

CLASSIFICATION.

The ore deposits of the Bay Horse district fall into two fairly well defined groups according to the principal metals contained. Thus they may be classified as lead-silver and silver-copper deposits, the two differing somewhat in form and geologic occurrence. The lead-silver deposits, though broadly tabular, are very irregular in detailed outline, in most places clearly showing the action of replacement processes or at least the filling of solution cavities. The silver-copper ores, on the other hand, occupy fissures of comparatively definite outline, which probably stood open at the time of mineralization. Closely related to this difference in the two groups is the unexplained fact that the lead-silver deposits are by far more commonly inclosed in dolomitic limestones and dolomites and the silver-copper deposits in slates and shales.

The silver-copper deposits have been more extensively explored than the others and have afforded about two-thirds of the total production of the district. Among the more important mines the Ramshorn, Skylark, and Silver Bell have produced this kind of ore, and the Red Bird, Beardsley, Excelsior, and River View have produced the other.

Both types of deposits afford high-grade ores, 60 to 80 ounces of silver being commonly associated with 40 to 50 per cent of lead, and 80 to 100 ounces of silver with 8 to 10 per cent of copper.

LEAD-SILVER DEPOSITS.

Distribution.—Lead-silver ores have been mined at widely scattered localities in the Bay Horse district. Between the Livingston group on the south and the Daugherty claims on the ~~north side of~~ 30 miles, similar ores have been found on Squaw ~~and~~ ^{1,} and in the east half of the area adjacent to Bay ~~Horse~~.

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Minerally the lead-silver deposits are rather simple. The primary ores consist predominantly of argentiferous galena, with which quartz and siderite are associated as gangue minerals. Tetraedrite, sphalerite, pyrite, and chalcopyrite occur in unimportant amounts. As mined, however, the ores are mostly earthy sand carbonate stained with iron and manganese. Anglesite, the lead sulphate, occurs as a transition stage in the alteration of galena to cerussite but is local in its occurrence and abundant only in parts of the Red Bird mine. Minium; the oxide of lead, was noted in one specimen from the Beardsley ore bins. The alteration products of the sphalerite are smithsonite and calamine, the former occurring as druses and the latter as sheaf-like bundles of crystals extending from the walls of cavities otherwise lined with smithsonite. Fluorite occurs in places in the oxidized ore of the Red Bird mine as small bluish-white cubes set on druses of smithsonite. In many of the deposits a large amount of manganese oxide colors the secondary ore, but the primary mineral from which it is the alteration product was not recognized. The iron oxide, abundant in the altered ores, results principally from siderite and subordinately from chalcopyrite and pyrite.

Analyses of ores from most of the mines were not available, but the compilation which appears on page 41 is probably fairly typical of the composition of roughly hand-sorted material.

SILVER-COPPER DEPOSITS.

Distribution.—Silver-copper veins, though less widely distributed in the district than the lead-silver deposits, have played an even more important part in its economic history. Three properties have produced considerable amounts of this type of ore—the Silver Bell mine, on Poverty Flat, and the Ramshorn and Skylark mines, at Bay Horse. The first is about 8 miles south of the other two. Some 6 miles north of Bay Horse a little gray copper also occurs in the ores of the Dougherty property at the head of Garden Creek. Thus this type of deposit is recognized at intervals along a north-south belt about 15 miles in length.

Geologic and structural relations.—All of the silver-copper deposits are inclosed in slates, presumably of Paleozoic age. The slates generally present a marked slaty cleavage at a high angle to the bedding, a structure locally so pronounced that the bedding planes are not discernible. The two principal deposits bear a definite relation to these structures; the Skylark vein follows the bedding and the Ramshorn the lines of slaty cleavage. The Silver Bell, however, occupies a fissure independent of either type of parting. All the deposits are fissure fillings, the fissures having opened along preexisting planes of parting

in the two larger deposits and in the other one along a zone independent of any such planes.

About 600 feet west of the Skylark mine and possibly 1,000 feet from the Ramshorn is a granite mass about a mile across. The slates adjacent to this mass present an appreciable metamorphism, characterized by the development of andalusite (?) and muscovite and to a minor extent of zoisite, actinolite, garnet, and rarely tourmaline. No igneous rock was seen in the immediate vicinity of the New Silver Bell mine.

Character of the deposits.—The silver-copper deposits are tabular in outline and conform closely to the walls of the fissures which they occupy. Bunches of ore isolated in the walls, such as are common in the lead-silver deposits of the district, are rare in the silver-copper deposits. Where offshoots from the main body occur they follow distinct lines of parting, as joints or bedding planes, and then are mere stringers, some of them little more than films of ore.

The ore occurs in shoots of irregular shape, which range in length from a few feet to 200 or 300 feet and in width from a few inches to 4 feet, the most common dimensions being possibly 100 feet by 20 inches. Their vertical extent is commonly two or three times greater than their horizontal extent. Within the veins shoots are distributed without apparent regularity, although they commonly show a tendency to occur one above the other and in the same deposits to pitch in the same direction. Along their margins the shoots wedge out or merge into comparatively barren gangue and gouge.

The ore.—The silver-copper ore as mined consists of two quantitatively important minerals and several others which, though persistent, are accessory. Siderite constitutes possibly three-fourths of the vein material and tetrahedrite one-third of the remainder. Among the accessory minerals quartz is by far the most abundant, but chalcopyrite is more evenly distributed. Galena, arsenopyrite, pyrite, and rarely sphalerite occur in small amounts. Secondary minerals are negligible in the deposits as now worked.

The siderite is coarsely crystallized and most commonly occurs in rhombic forms, as in Plate VII, *B* (p. 33), but locally in elongated forms (Pl. VII, *C*) and as lamellar crystals lining small cavities. Tetrahedrite occurs in bunches, which cut across the siderite crystals or follow their cleavage planes. A complete analysis of the tetrahedrite appears on page 34. The quartz is intergrown with the siderite in most places, but locally occurs as beautiful doubly terminated hexagonal crystals, either embedded in the siderite or perched against the sides of small cavities in the tetrahedrite. Chalcopyrite occurs as netlike films along numerous minute fractures in the ore and as linings of small cavities in the tetrahedrite. Galena occurs as small grains and crystals intergrown with the tetrahedrite or clustered in cavities in it. Less abundant than the chalcopyrite, though

probably formed before most of it, is arsenopyrite, which occurs as grains and columnar crystals, generally related to fractures in the siderite (Pl. VII, *C*). The only sphalerite seen in the deposits occurs as minute crystals set upon free faces of galena in cavities in the Ramshorn ore.

The tenor of the ore varies according to the amount of tetrahedrite it contains. Specimens of this mineral from the large ore shoot in the Ramshorn mine contained 33.39 per cent copper and 4.86 per cent silver (or 1,417 fine ounces to the ton). The average tenor of the ore in this shoot is said to be 3 per cent copper and about 125 ounces in silver to the ton. By roughly hand sorting, however, this grade may be greatly raised. The Skylark ore, on broad averages, is said to have contained 8 per cent copper and 80 to 100 ounces silver to the ton, although some of it ran 12 per cent copper and 600 to 700 ounces in silver.

Little information is available concerning the nature and tenor of the ore from the old Silver Bell workings, but it occurred so near to the surface that oxidation was probably well advanced, the tetrahedrite being altered to carbonates of copper and chloride of silver. It is said that chalcocite was rare.

AGE AND GENESIS.

The two types of deposits recognized in the Bay Horse district are closely related in age and as phases mineralogically intermediate between the two occur, they are thought to have had practically the same origin. They have a wide vertical range, the difference in elevation between the Ella mine, at Clayton, and the Silver Bell mine, on Poverty Flat, being about 3,000 feet. No single ore body has been traced throughout this extent, but the Ramshorn vein has been explored to more than half that depth and ore found on all the levels.

The higher deposits, such as those on Democrat Hill, the Ramshorn and Skylark veins, and the Silver Bell, are truncated by the Eocene erosion surface and hence are older than late Eocene. On the other hand, they are inclosed in Paleozoic sedimentary rocks, which probably range from Cambrian to Devonian, perhaps younger. Closer than this the age of the deposits can not be determined from local evidence, but from the broad considerations outlined on pages 35-36 it is concluded that they were formed shortly after the intrusion of the granitic rocks, which are considered to be late Cretaceous or early Eocene.

Their genesis is more difficult of determination. The conclusion that they were formed at great depth follows from the similarity in the mineralogy of the ore found at different elevations in the mines, for if conditions of deposition were the same throughout the range of 2,000 to 3,000 feet, the upper part must have been sufficiently below

the then existing surface to exclude the influence of oxidizing surface agencies. Aside from this, however, there are physiographic reasons (see p. 36) for believing that a vast amount of erosion took place after the deposits formed and before the elevation of the Eocene erosion surface—probably more than 5,000 feet of beds were removed.

The deposits are thought to be genetically related to the intrusive masses of granitic rocks—a relation discussed in the general section, pages 35–38, 41–42.

MINES AND PRINCIPAL PROSPECTS.

RAMSHORN MINE.

Situation and development.—The Ramshorn mine comprises seven patented claims situated on the north side of Bay Horse Canyon about 2 miles above Bay Horse. Development consists of 15 tunnels which enter along the strike of the vein at unequal intervals through a vertical range of about 1,650 feet. From highest to lowest the tunnels are designated Ramshorn Nos. 1 to 7, Utah Boy Nos. 1 to 5, and Post Boy Nos. 3 to 1. Above the Utah Boy No. 3 most of the tunnels are inaccessible, but those below are open. Raises connect the several levels and above the Utah Boy No. 2 are large stopes from which the early production was derived. In all there is perhaps 6 or 7 miles of development on the property.

History and production.—The Ramshorn mine was located in August, 1877. Development began soon thereafter and was pursued actively most of the time until the fall of 1897. Since then a watchman has been kept at the mine and a small amount of tunnel work accomplished each year. During the period of activity the ore was conveyed by aerial tram from the upper tunnels to the bottom of the canyon and thence by wagon to the smelter at Bay Horse. The total production of the property is said to have been about \$3,000,000.

Geologic relations.—The Ramshorn mine is situated well within the area of slates that forms the western limb of the anticline which centers near Bay Horse. The slates are all fine grained and characterized by an abundant development of sericite. In some of the slates which outcrop on the lower slopes of the canyon side at the mine small elongated crystals, possibly andalusite but now completely altered to calcite, stud rather evenly the otherwise fine-grained mass. In color the slates vary from dull to light gray, though locally they present a greenish cast. Slaty cleavage is well developed and in places completely obliterates the bedding structure, across which it cuts at an angle of about 50°. The ore bodies follow fissures which parallel the slaty cleavage, though locally stringers extend out along the bedding planes.

The veins.—The vein fissures strike N. 15°–30° W., and dip 57°–85° SW., the average strike being about N. 15° W. and the most common

dip about 80° SW. Above the lower three levels two parallel veins 30 to 50 feet apart are recognized, but below them only one has been encountered. In each a zone of crushed wall rock, 3 to 6 feet wide, follows the fissure and is generally present even where mineralization is lacking. In these parallel fissures the ore bodies occur in shoots, which alternate from one fissure to the other. Thus in many places where the ore body pinches out in one fissure a crosscut to the other one has revealed another shoot.

The veins are bordered by well-defined walls, though locally stringers extend into the country rock. In general, the fissures parallel the cleavage of the inclosing slate, but in a few places ore follows the bedding planes, which dip westward at a much lower angle. This is thought to explain the difference in dip between the ore body in the Post Boy tunnels and that in the Utah Boy tunnels. Nos. 3, 4, and 5.

Faults are not numerous in the mine, only two being seen during the hasty examination, both of which occur in the Utah Boy section of the vein, to which they are parallel in strike but opposite in dip. In each of these faults the hanging wall has moved down about 25 feet relative to the footwall.

The ore.—The ore is essentially gray copper in a siderite gangue. Associated with the tetrahedrite are unimportant amounts of pyrite, galena, chalcopyrite, arsenopyrite, and sphalerite. Quartz occurs as isolated euhedral crystals, which stud sparsely the siderite gangue, and as irregular patches intergrown with the metallic minerals. A complete analysis of the tetrahedrite, which contains 4.86 per cent silver (equivalent to 1,417 fine ounces per ton) and 33.39 per cent copper, appears on page 34. This mineral is present on all levels of the mine, but the largest body found lies between the Utah Boy tunnels Nos. 3 and 4. Here occurs a shoot of ore, which on No. 4 level is between 350 and 400 feet long and continues upward to No. 3 level, 140 feet higher, although there the north end draws southward, shortening it many feet. The ore averages about 2 feet in width and is made up principally of tetrahedrite and siderite in such proportions that the average ore contains 3 per cent copper and 100 ounces of silver per ton. The tetrahedrite occurs in bunches both along cleavage planes of the massive siderite and as tabular bodies cutting across them. In general the tetrahedrite attains its maximum development on the footwall side of the vein.

The paragenesis of the ore minerals is discussed on page 33.

SKYLARK MINE.

Situation and development.—The Skylark mine is situated immediately west of the Ramshorn on the same side of Bay Horse Canyon. The property comprises 9 or 10 claims, two of which

are patented. Development consists of 16 principal tunnels, which enter at unequal intervals along 2,000 feet of the outcrop of the vein and represent in all perhaps 25,000 feet of work. The tunnels are divided into east and west groups with the old boarding house as datum. Thus they are known as Nos. 1 to 7 east and Nos. 1 to 10 west. All the ore is said to have been removed above No. 7 west.

History and production.—The property was located in 1877 and in 1880 was purchased by the Omaha Smelting & Mining Co., which recently sold it to the Idaho Smelting & Mining Co. In 1883 the Ramshorn Mining Co. had the property bonded for \$35,000, but owing to the poor showing of ore they allowed the option to lapse. A short time thereafter the ore bodies which afforded the principal production were encountered and for several years the mine was an important producer of silver and copper. A great deal of the ore was smelted at Bay Horse, but far more was sent by pack trains over the summit, 12 miles to Clayton. After the Clayton smelter was closed in 1902 considerable ore was shipped by leasers to Salt Lake and Denver at a cost of about \$30 per ton for freight and treatment. The charge for treatment by the local smelters was \$18 and \$20 per ton, the lower charge applying when the amount of lead exceeded a stated percentage.

The total production of the property is said to be \$2,700,000, derived from ore which averaged about 8 per cent copper and 80 ounces of silver per ton.

Geologic relations.—The vein is inclosed in greenish-gray thin-bedded sericitic slates, which strike N. 8° W. and have a general dip of 22° SW., although locally as steep as 60°. These extremes of dip were recorded in tunnel No. 9 west, where for 250 feet from the portal the beds dip about 60° and then abruptly dip 22°. The plane of transition is an east-west fault, which displaces the north-lying beds 50 or 60 feet east. Westward from the mine the thin-bedded slates grade into micaceous quartzites, which occur in beds 5 to 10 feet in thickness. These quartzites continue as the predominant type of rock to a point possibly 500 feet west of tunnel No. 9 west, where granite comes to the surface as a mass about a mile across. At the border of the granite an andalusite-like mineral (p. 33) is abundantly developed in the sedimentary rocks, as well as muscovite and biotite. This metamorphic effect contrasts rather sharply with that which accompanies the ore bodies, where calcite and sericite are the important alteration products.

The vein.—The vein follows the bedding of the inclosing formation. In most places there is an appreciable brecciation along the particular bedding plane which the ore follows, but this is in few places more than 3 feet wide and is bordered by firm walls. Within this general crushed layer the ore occurs in irregular lenslike shoots, which are

usually elongated parallel to the dip, but few of which have proved continuous for more than 200 or 300 feet, most of them having given out within 100 feet. The old workings were not safely accessible at the time of visit, but an inspection of an old mine map showed more than 40 such lenses of ore to have been worked. The tenor of the ground between the old stopes is not known to the writer, although it should be borne in mind that at the time this portion of the vein was worked the cost of mining and treatment was about \$25 to the ton of ore. Thus it is thought to be highly probable that a considerable tonnage of medium-grade ore remains in the abandoned workings. Another possible source of ore may be vertical veins which follow the slaty cleavage, as in the Ramshorn mine. Apparently all of the development has been along the bedding planes, yet there seems to be no particular reason why the ore-bearing solutions should have followed one set of major partings to the total exclusion of the other.

The ore.—The Skylark ore, like that of the Ramshorn mine, is essentially gray copper in a siderite gangue. Accompanying the tetrahedrite in very subordinate amounts are chalcopyrite, arsenopyrite, galena, and less pyrite and sphalerite. In the oxidized ore cerargyrite and the carbonates of copper were common, and argentite, leafy native silver, wire silver, pyrargyrite, and native copper were occasionally found. The average width of the ore bodies is said to have been about 20 inches, the ore in general running 8 per cent copper and 80 ounces in silver to the ton. Some of it, however, ran several hundred ounces in silver and up to 20 per cent copper.

RIVER VIEW MINE.

The River View mine is situated $1\frac{1}{2}$ miles southeast of Bay Horse, well up on the cliff which faces Salmon River. This claim was staked in March, 1877, and was the earliest location in the district. Development consists of several tunnels and a 100-foot shaft, in all perhaps 5,000 or 6,000 feet of work. The total production of the mine is said to be \$500,000, derived principally from silver-lead ores.

The deposit is situated within the area of dolomitic limestone on the east limb of the Bay Horse anticline. The limestones occur in massive beds, which vary in color from sky-blue to bluish gray. Joints traverse them in various directions; the most conspicuous, perhaps, strike N. 60° W. and dip 80° NE. Eastward the dolomitic limestones are covered within a short distance by lacustrine deposits and lavas of Tertiary age.

The ore occurs in irregular lenses and bunches, and as parallel stringers alternating with quartz and limestone, and represents about one-fourth of a zone 5 feet wide. The larger lenses conform to the bedding planes, and most of the stringers and bunches are related to

joints. Those parts of the workings which were visited have been stoped, but good ore is said to occur in drifts from the bottom of a shaft, now inaccessible. Near its collar, however, is a pile of ore, containing perhaps 400 tons. This ore is for the most part argentiferous galena accompanied by a little sphalerite and is associated with a porous manganese-stained quartz. Much of it is oxidized, the secondary minerals being cerussite, a little argentite and native silver, malachite and azurite, and small amounts of smithsonite.

EXCELSIOR MINE.

The Excelsior mine comprises one claim situated at an elevation of 6,600 feet, on the east side of Beardsley Gulch, about 1,500 feet north-east of Bay Horse. Development consists of a principal tunnel and a winze which attains a depth of 500 feet. The production of the property is not known, although the total output of the ore body which is common to this and the Beardsley mine is stated as 1,500,000 ounces of silver and 15,000 tons of lead.¹

The mine is situated near the axis of the Bay Horse anticline and is well within the area of dolomitic limestone. The surface workings (the only part accessible) are inclosed in this type of rock, but it is probable that the lower levels extend into the calcareous and dolomitic slates which outcrop at the base of the cliff a short distance south.

The chief ore body was a large lenticular mass which varied from 100 to 200 feet in length and from 1 to 20 feet in width. The ore was sand carbonate heavily stained with iron and manganese, and ran from 40 to 60 per cent of lead and 50 to 60 ounces of silver to the ton. At a depth of about 500 feet the rich ore is said to have given way to disseminated material of much lower grade.

BEARDSLEY MINE.

The Beardsley group comprises four patented claims in Beardsley Gulch, the principal workings being situated about midway of the group and half a mile above Bay Horse. The mine has not been worked for 20 years and at the time of visit was extensively caved. The development consists of several tunnels and a winze on the ore; the latter attained a depth of 500 feet.

The inclosing rock is gray dolomitic limestone, which is intricately jointed in various directions and fissured along north-south courses. The fissuring parallels the crest of the anticline near the longitudinal axis of which the deposit occurs.

The principal ore body followed a north-south fissure and varied in width from 1 to 20 feet or more. The shoot, which was from 100 to 200 feet long, extended south into the Excelsior ground, and is said

¹ Bell, Robert, An outline of Idaho geology and of the principal ore deposits of Lemhi and Custer counties, Idaho: Proc. Internat. Min. Cong., 1901, p. 73.

to have yielded about 1,500,000 ounces in silver and 15,000 tons of lead from a sand carbonate ore. Of the several tunnels only the northernmost one was accessible at the time of visit. In this tunnel 300 or 400 feet of work has been done on a ledge which strikes north-south and dips 30° E. The deposit, which consists of innumerable veinlets of ore along fractures and bunches in the solid limestone, is extremely irregular. The bunches range from lumps the size of baseballs to masses 14 or 15 feet across, yet all distributed along a zone perhaps 40 feet wide which dips 30° E. The minerals are iron-stained sand carbonate and cerargyrite, the latter in minute grains identifiable with difficulty. Stains of copper carbonate and druses of smithsonite are common; sheaf-like aggregates of calamine crystals are less numerous. It is said that the purer grades of ore ran 40 to 60 per cent lead, 2 to 3 per cent copper, and 50 to 60 ounces in silver to the ton.

PACIFIC MINE.

The Pacific claim is now one of the McGregor group, but as it has commonly been considered a separate mine it will be described separately here. It is situated at an elevation of 7,800 feet on the northeast slope of Democrat Hill, about 1½ miles northeast of Bay Horse. The property has produced \$65,000 from the two short tunnels, which total perhaps 1,000 feet in length and comprise its only development.

The deposit, which follows the flat-lying beds of the massive dolomite that forms the summit area of Democrat Hill, varies in width from narrow stringers to 5 or 6 feet. The ore is locally clean sand carbonate, though in most places quartz is the predominant mineral. Commonly the ore extends as irregular bunches into the adjacent wall rock or leads off along joints and narrow fissures. The ore minerals are sand carbonate, cerargyrite, smithsonite, and a little argentiferous galena, so proportioned in a quartz gangue that average shipments of hand-picked material run 50 to 60 per cent of lead, 60 to 80 ounces of silver, 2 to 3 per cent of zinc, 4 to 6 per cent of sulphur, and 20 to 25 per cent of silica. Two partial analyses of the inclosing dolomite, which were supplied by Mr. James McGregor, of Salt Lake City, owner of the property, are as follows:

Partial analyses of country rock at Pacific mine, Custer County, Idaho.

	1	2
Silica.....	7.00	5.1
Lime.....	35.00	30.00
Magnesia.....	14.63	20.18

HOOSIER GROUP.

The Hoosier group, recently consolidated with the McGregor group, consists of four claims situated on the lower slopes of Bay Horse Canyon, a few hundred feet above the Beardsley mill. (See fig. 2.) The development consists of several short tunnels on either side of the creek, in all perhaps 2,500 feet of work.

The principal deposits are two parallel veins about 60 feet apart. They strike north-south, dip 22° W., and are inclosed in the shales and slates which at this place extend well up the valley sides. The upper or west vein ranges from 1 inch to 4 feet in width, averaging about 2 feet. Pyrite associated with coarsely-crystallized quartz is the most common metallic mineral, though tetrahedrite, which occurs only locally, is the mineral sought. Hand-picked shipments from this ledge contained 20 to 25 per cent copper and 200 to 400 ounces in silver to the ton. To such ore a production of about \$50,000 is credited. The lower vein differs from the upper in that little tetrahedrite is present, the dominant ore mineral being argentiferous galena. This vein averages about 15 inches in width, but the valuable constituents occur only in small irregular patches in its general plane. It has produced about \$20,000 in silver and lead.

A remarkable feature of both veins is a mass of clear-white, coarsely crystallized barren quartz which overlies them. The quartz above the upper vein is 10 to 12 feet thick; that above the lower, 40 feet thick. This quartz is almost if not altogether devoid of metallic inclusions. Locally a thin clayey seam separates it from the veins, but elsewhere the quartz cuts the ore. The country rock is a slate so fissile that the footwall of an open, flat-lying fissure in it would have been covered before long with fragments from the roof. No such rubble is present on the upper surface of the ore, which suggests that the incoming quartz material followed quickly the opening of the cavity or perhaps caused it.

SILVER BRICK CLAIM.

The Silver Brick claim, also one of the McGregor group, joins the Pacific on the west. The development consists of two tunnels 100 feet apart vertically, the lower 700 feet and the upper 150 feet in length. The ore occurs irregularly along a fissure which strikes N. 10° W. and dips 40° NE. A small production has resulted from stopes between the two levels.

The inclosing rock is a dolomite similar to that at the Pacific mine.

CAVE MINE.

The Cave mine, owned by Christopher Peterson, a local resident, comprises a single unpatented claim situated about a mile northwest of Bay Horse, at an elevation of 8,100 feet on the south slope of Democrat Hill. Development consists of a shaft and an 840-foot tunnel in

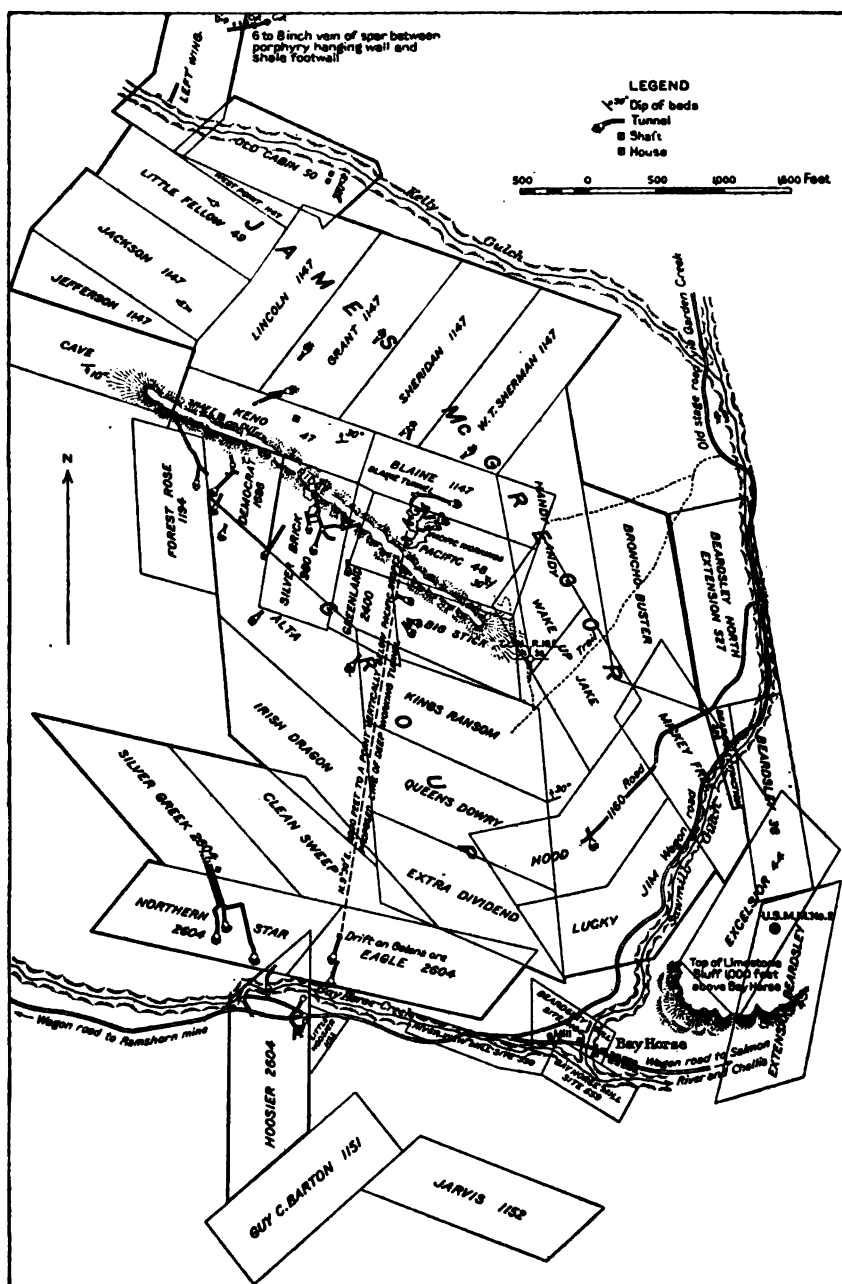


FIGURE 2.—Claim sheet of James McGregor group, Bay Horse district.

addition to various drifts and crosscuts, in all perhaps 1,500 feet of work. Two veins which strike N. 20° W. and dip 70° NE. are recognized, but only one has proved productive. This vein is a band of ore about 18 inches in average width, which is accompanied by a variable amount of gouge, the usual distance between the fairly well defined walls being about 4 feet. The ore contains lead and silver and is similar to that found in the Beardsley and Pacific mines. In the outer part of the tunnel thin-bedded slates dipping 10° S. pass in a short distance through more massive varieties into the underlying dolomite which incloses the veins.

FOREST ROSE MINE.

The Forest Rose group, consisting of three patented claims, lies immediately south of the Cave property on Democrat Hill. It is situated on the same ledge which is worked in the Cave mine, but the shoots here found have been less productive. Development consists of a tunnel 600 feet long and two raises on the ore. The ore occurs in shoots, which range in width from a few inches to 5 or 6 feet. These appear to strike north-south and to dip approximately 60° E., although development is not sufficient to determine their attitude definitely. The ore is partially oxidized argentiferous galena. At present the property is being worked by lessees.

NEW SILVER BELL MINE.

The New Silver Bell mine (formerly known as the Silver Bell) is situated on the east margin of Poverty Flat at an elevation of 9,500 feet. The mine is reached by trail from Clayton, 4 miles on a direct line south-southeast. The deposits were discovered in 1879 and were worked for the 18 years following, having produced in all about \$600,000 from silver-copper ores. The property comprises five unpatented claims and is developed to a maximum depth of 100 feet by some 10,000 feet of tunnels.

Poverty Flat is a remnant, several miles in extent, of an Eocene erosion surface developed at this locality across steeply tilted slates and quartzites of Paleozoic age. The quartzites are fine-grained and massive; the slates thin bedded and fissile, in many places with marked slaty cleavage. The ore deposits are found within the slates.

The vein strikes N. 60° W. and dips 30° NE. It follows the inclosing formation in strike but is independent of it in dip, cutting across both the primary and secondary structures. The vein is said to have steepened with increasing depth. Within a general zone of fissuring, perhaps 100 feet wide, ore occurred as narrow lenses of irregular shape and unequal extent. The ore consisted of gray copper in a siderite gangue and is similar to that of the Ramshorn and Skylark mines, although the shoots here were much less continuous. In many places

along the vein ore was mined within 5 or 10 feet of the surface, where the copper occurred principally as malachite and azurite and the silver as cerargyrite and argentite. The claims have recently been relocated and are now being prospected at greater depth.

ELLA GROUP.

The Ella group comprises four claims situated on the south slope of Kinnikinnick Canyon near its junction with that of Salmon River. Development consists of several tunnels, the longest of which starts near Clayton and continues 1,600 feet on a course N. 15° W. This tunnel follows the general strike of the Paleozoic formations which constitute the country rock. The ore occurs along bedding planes between a general hanging wall of dolomitic limestone and a footwall of fine-grained quartzite. Very little ore appears in this tunnel, but a considerable amount of argentiferous galena in a quartz-siderite gangue lies on the dump. Pyrite and tetrahedrite are intermixed with the galena but in subordinate amounts.

The group produced a considerable tonnage during the early days of mining in the district, but most of it was derived from openings which are farther up the canyon and are now inaccessible. The ore was desired because of its high content of siderite, which served as a flux in smelting other ores of the district.

RED BIRD MINE.

Situation and history.—The Red Bird mine is situated on the east side of Squaw Creek, 5 miles above its confluence with Salmon River and by wagon road 9 miles northwest of Clayton. The deposit, situated near the north end of a group of 10 claims (fig. 3), was located in 1878, and the active work, which continued until 1902, was begun in 1880. During this period from 1,000 to 1,500 tons of ore which ran 30 to 40 per cent of lead and 40 to 60 ounces of silver to the ton were delivered to the Clayton smelter annually.¹

The mine is opened on eight levels by five tunnels, the upper four of which enter the canyon side at intervals of about 100 feet. All the tunnels are connected by raises and between Nos. 4 and 8 are three blind levels, the total development aggregating 10,000 to 15,000 feet. Most of the production came from the upper four levels, which represent a depth on the ore shoots of 600 to 700 feet. Below this depth little ore had been mined at the time of the writer's examination, but since then this portion of the deposit has been extensively worked.

Geologic relations.—The Red Bird mine is well within the area of Paleozoic rocks. The sharp anticline cut across by Salmon River

¹ The mine was reopened in 1912 by the Idaho Smelting & Mining Co. and has been actively worked since, supplying most of the ore for the Clayton smelter.

between Squaw Creek and Clayton continues northward, and these deposits occur on its western limb. The rocks inclosing the ores are

predominantly dolomitic slates; but locally dolomitic limestone and clayey quartzite occur. The lower tunnel crosscuts the beds for 1,600 feet and affords a fair idea of the formations and their attitudes. Thin-bedded calcareous slates, dipping 70° W., prevail for the first 80 feet of this tunnel, but from this point they grade rapidly into more massive varieties and the dip flattens to the horizontal. About 600 feet from the portal the beds are steeply inclined eastward and the thin-bedded slates seen near the portal again appear, but within a short distance give way to massive dolomitic limestone, which continues to a point 1,400 feet from the entrance. From this point on to the face at 1,600 feet the beds are nearly horizontal and argillaceous quartzite predominates.

The ore bodies.—At least five ore bodies have been encountered in the mine, but two have proved of paramount importance. One of these bodies, known as the Potato Patch shoot, was 60 to 80 feet long by 20 to 30 feet wide and was worked to a depth of more than 400 feet. Its strike

was N. 65° W., and its dip 45° SW. The ore throughout was an earthy mass of sand carbonate which ran 30 to 40 per cent of lead

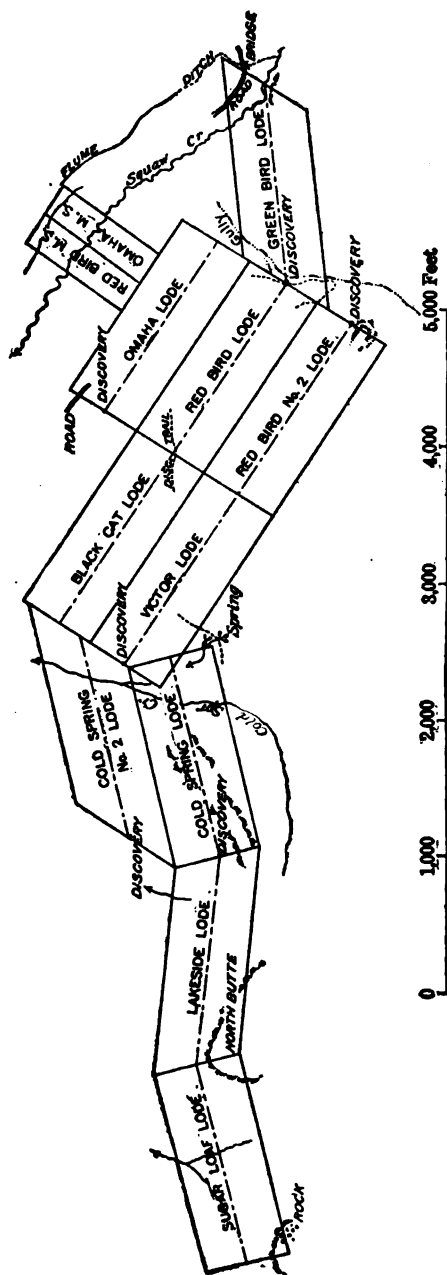


FIGURE 2.—Claim sheet of Red Bird group, Bay Horse district.

and 40 to 60 ounces in silver to the ton. Although of broadly regular outline, the old stopes show the ore body to have been irregular in detail. Here and there it extended out along joint cracks; elsewhere great swells protruded into the inclosing rock.

Parallel to this shoot and about 150 feet east of it is another, which on No. 2 level corresponds to it in strike and dip but on the lower levels changes to a strike of N. 20° W. and dips 40° NE. A considerable tonnage of ore is blocked out on this shoot between No. 2 and No. 8 levels. Within it the ore occurs in bunches of irregular shape and extent which, however, usually have a roughly tabular form parallel to the general plane of the fissure. In places the bunches give way to a veinlike mass 50 to 75 feet in length and as much as 12 feet in width, as near No. 2 level. The ore is similar in general character to that in the west shoot and is fairly continuous to a point within 65 feet of No. 8 level, where it gives way to a mass of pyrite 55 feet wide at the only point where it has been crosscut. This pyrite carries traces of gold and an unimportant amount of copper. It is exceptionally vuggy throughout the mass. The vugs are lined by pyritohedrons of pyrite and here and there a little manganese oxide. Among the minerals which occur in the productive part of this shoot, sand carbonate heavily stained with iron and manganese is most common. Minute grains of cerargyrite occur with it and vugs in the ore are commonly lined with crusts of smithsonite. Set upon these smithsonite druses are needlelike crystals of calamine and bluish-white cubes of fluorite. In protected spots only do the primary minerals, argentiferous galena, pyrite, and sphalerite, occur. Anglesite occurs in places as the principal ore mineral in this shoot. It contains 2 to 3 ounces of silver to the unit of lead, whereas in the carbonate ore there is only 1 ounce of silver for each 1 per cent of lead, the latter ratio being about the same as in the argentiferous galena, in which 0.5 to 1 ounce of silver accompanies each unit of lead.

Since the writer's examination a large ore shoot has been found on No. 7 level and penetrated for 60 feet, although its dimensions have not been determined.

SATURDAY GROUP.

The Saturday group consists of two patented claims situated on the west side of the canyon near the mouth of Squaw Creek. The development consists of a shallow shaft and one or two tunnels, all of which date from the early days of mining in the district. The property is said to have produced a few thousand tons of argentiferous galena ore but has not been worked for 20 years or more.

CINNABAR GROUP.

The Cinnabar group comprises two patented claims situated 5 miles up Bruno Creek, a northwest tributary of Squaw Creek, which it joins at a point 2 miles below the Red Bird mine. The property was not visited but is said to have produced about \$100,000 from lead-silver ore. At a later date it was sold as a gold mine to certain eastern speculators, but as such it proved a total disappointment.

SOUTH BUTTE GROUP

C. L. Tracht owns a small group of claims immediately east of the Red Bird mine, which produced about 1,000 tons of argentiferous galena ore in the early days and have been worked intermittently by leasers during the past few years. They were not visited.

DOUGHERTY GROUP.

The Dougherty group, consisting of seven claims, is situated on Garden Creek, 9 miles west-southwest from Challis, at an elevation of 7,700 feet. The development consists of six tunnels on the north side of the gulch and two on the south side—in all, perhaps, 2,000 feet of work. The deposits are irregular lenses inclosed in dolomitic limestone and thin-bedded slates. Two types of ore are recognized—argentiferous galena and tetrahedrite accompanied by pyrite and chalcopyrite. In general the strike is N. 50° W. and the dip 30° SW., but in no place has a sufficiently continuous deposit been exposed to determine any persistent attitude.

LIVINGSTON MINE.

The Livingston group, consisting of five or six patented claims, is situated near the head of Slate Creek, about 9 miles from Salmon River and 20 miles southeast of Clayton. This property was not visited during the reconnaissance, but its promise is such that it deserves special mention.

The development consists of about 600 feet of tunnels and several open cuts on a ledge said to be remarkable for its continuity. The production amounts to \$40,000 or \$50,000, which has resulted from ores removed during development. The property has been sampled several times and would probably have been worked before this were it not for its comparative inaccessibility. It is said that a large tonnage of silver-lead ore is partially blocked out.

YANKEE FORK DISTRICT.**SITUATION.**

The Yankee Fork district comprises an unorganized area of possibly 150 square miles situated in the northwestern part of Custer County. It lies south-southeast of the Loon Creek district, northeast of Stanley

Basin, and west of the Bay Horse district—about 20 miles from each. There are three settlements in the area—Bonanza, Custer, and Sunbeam—all grouped within a radius of 5 miles from the junction of Jordan Creek with Yankee Fork. The settlements have regular stage communication with Challis, 60 miles distant by a route which follows Yankee Fork and Salmon River. Mackay, the nearest railroad point, is 85 miles southeast by a route which leaves the Challis stage road near the confluence of East Fork with Salmon River. Roads also connect north-northwest with Loon Creek district and southwest with Stanley Basin. A trail which is used a great deal leads over the mountains to Challis, 30 miles northeast.

HISTORY.

Prospectors spreading from the placer excitement on Loon Creek discovered placer gold on Jordan Creek near its confluence with Yankee Fork in the middle seventies of the last century. Soon thereafter the lodes on Dickens Hill and those about Custer were located and quickly drew attention from the placers. The General Custer vein was especially attractive to those seeking lode deposits, for it lay against the canyon side as a great slab several thousand square feet in extent and promised strength and persistence together with exceptional amounts of the precious metals. In many respects, however, it was misleading. Developments have failed to add more than 20 per cent to its productive area as exposed by erosion and none of the other veins have even approached it in total production.

The district experienced its greatest activity prior to 1900, though the General Custer mill operated most of the time until 1905. After that mining operations were unimportant until 1907, when the Golden Sunbeam was opened on a large scale, a mill built, and a hydroelectric plant installed on Salmon River. In 1911, however, this enterprise also was temporarily abandoned, leaving the entire district inactive.

PRODUCTION.

The total production of the Yankee Fork district is estimated at \$12,000,000, two-thirds of which is credited to the General Custer vein. Of the remainder about one-third was derived from the Lucky Boy and the rest principally from the Charles Dickens, Golden Sunbeam, Montana, Morrison, and McFadden properties.

The relative importance of gold and silver in making up the total production can only be roughly approximated. During the twenty-odd years that the camp was active the price of silver varied greatly, as did also the amount of bullion produced each year. The latter factor is not known, hence the only means of estimating the separate amounts of gold and silver produced is a survey of their relative importance in the ores of individual mines. The General Custer,

Lucky Boy, and Charles Dickens veins contained about 85 ounces of silver to 1 of gold. These properties produced three-fourths of the total amount derived from the district. The Montana and Golden Sunbeam contained much more gold than silver, but their combined production was less than a million dollars. In the other veins in the camp silver exceeded gold in amount. Thus considered, it is estimated that about 40 per cent of the total production of Yankee Fork district has been from gold and the remainder from silver.

TOPOGRAPHY.

The Yankee Fork district is a high, mountainous area which varies in elevation from 6,000 to 9,500 feet. Yankee Fork, a stream which flows south-southwest through the district, occupies the principal valley. Tributary to it from the west are Cabin, Jordan, and Eight-mile creeks, and from the east a number of small streams of minor importance.

The dominant feature of the higher areas is the general accordance of summit levels, a feature conspicuous from any point of vantage. This is somewhat remarkable, for most of the rocks in the district are Miocene tuffs, and the plateau surface of this part of Idaho is of Eocene age. The key to the explanation, however, is afforded by the water-laid tuff, which appears at elevations of 9,000 feet on Estes Mountain and is well exposed at 8,800 feet along the road over Loon Creek Summit. This tuff clearly bespeaks a Miocene water surface, which stood at about the level of the Eocene erosion surface, at least locally, and probably over a considerable area. The present valleys of the district are in large part cut in these volcanic rocks and hence are obviously post-Miocene in age.

Among the minor features of topographic interest is the valley of Yankee Fork below the mouth of Jordan Creek. Above this point it is comparatively narrow, but below it broad terraces follow the stream to its junction with Salmon River. These terraces in many places extend back 500 or 1,000 feet from the present channel. Locally the gravels composing them are more than 90 feet deep, though usually their thickness is less than 25 feet.

GEOLOGY.

ALGONKIAN ROCKS.

Distribution.—Rocks of Algonkian age¹ are exposed locally in the district. They outcrop along the sides of Yankee Fork valley for a distance of about 3½ miles, beginning at a point 2 miles below Bonanza and continuing southward. They are said to continue a short distance to the west, but to the northeast they open out into a broad

¹ For age determination see pp. 18-19.

area along the eastern border of the district. A small isolated area of the same system of rocks is exposed in the bottom of Jordan Creek valley near Sunbeam.

Composition.—Within this district the Algonkian system is represented by dark-gray massive quartzites, mica schists, massive black slates, and thin-bedded gray slates. Their sequence was not determined. Metamorphism is well advanced throughout, slaty cleavage and schistosity in most places concealing the original bedding structure. Sufficient primary structure remains, however, to indicate unmistakably their sedimentary derivation.

LATE CRETACEOUS OR EARLY EOCENE GRANITE.

The late Cretaceous or early Eocene granite, which is widely exposed in Idaho, is found only in the south part of this district, where it forms the walls of Salmon Canyon near the mouth of Yankee Fork. Northward from this point granite outcrops for about $2\frac{1}{2}$ miles, but to the east, west, and south its extent is much greater. A description of the rock constituting this area appears on pages 21-22.

TERTIARY VOLCANIC ROCKS.

Distribution.—Tertiary volcanic rocks are widely exposed in the Yankee Fork district, extending through it as a broad belt in a north-east-southwest direction. Their maximum thickness is not definitely known, although near Sunbeam they are exposed in uninterrupted succession through a vertical range of 3,000 feet, the lowest member resting on Algonkian beds. They occupy a post-Eocene erosion valley, and as the Sunbeam exposure is near the center of this old valley, it may be safely assumed that the exposure there presents approximately the maximum thickness.

Composition.—In general the volcanic rocks of this area are andesites and latites below and andesitic and rhyolitic tuffs, with interbedded andesite or latite flows, above. In the western part of the district the series is chiefly tuff, but east of Custer lavas, principally andesites, predominate. Northeast from the Enterprise mine numerous low hills, which attain perhaps 8,000 feet elevation, present excellent sections of parts of the lava series. These were not visited, but as seen from a distance of a mile or so eight or ten distinct flows of lava, each 10 to 25 or 30 feet in thickness, were recognized. About the Enterprise mine and over the summit to the Lucky Boy andesites are predominant, but toward Custer, at an elevation of 1,500 feet lower than the summit, tuffs are present in thick beds. Below these beds andesites are again exposed in the valley sides near Custer. Northwest of Sunbeam, along the road to Loon Creek, the Tertiary rocks are predominantly of different type, tuffs being very abundant and, together with a few lava flows, outcropping through a vertical

range of possibly 2,000 feet. In places the tuffs are massive, but elsewhere they are thin-bedded, even finely laminated, and were clearly deposited in standing water. An exposure of this variety forms Loon Creek Summit, but here siliceous shales are interbedded with the tuffs. The west face of Estes Mountain, as seen from Loon Creek Summit, presents the chalky white slopes typical of the areas of tuff.

Petrographic descriptions of these volcanic rocks appear on pages 25-26.

QUATERNARY DEPOSITS.

Evidences of glaciation appear on all those parts of the Yankee Fork district which exceed 7,500 feet in elevation and in places morainal débris and U-shaped valleys extend to elevations 500 or 1,000 feet lower. Jordan Creek valley is glaciated as far as Sunbeam. Glaciers radiated from Estes Mountain and left topography especially typical of their action on the north slope and down the valley of Eightmile Creek. About the Lucky Boy and Enterprise mines also glacial deposits are widespread.

The thick gravel deposits along Yankee Fork are thought to date from the period of general ice retreat which closed the Pleistocene. These gravels indicate the overloading of a stream which earlier in its history actively eroded its channel, and it seems that only during the period of ice recession were conditions favorable for this excess of material. At this time there was an abundant supply of running water, and a proportionately greater supply of rock rubble was loosened and in part ground up by the glaciers. As the ice front retreated this material was continually available for transportation, and the streams, if fully loaded in their upper swifter parts, must necessarily deposit nearer to their mouths, where the grade was lower. This was the condition along the valley of Yankee Fork.

ORE DEPOSITS.

GENERAL CHARACTER.

The ore deposits of the Yankee Fork district are exclusively gold-silver veins inclosed in volcanic rocks of middle Tertiary age. In some of the deposits gold is present almost to the exclusion of silver and in others silver is greatly in excess. Copper and lead are much more abundant in these veins than is common in the late Tertiary deposits, though in none of them are these metals in sufficient quantities to constitute an ore.

The veins were worked for a number of years at a large profit, but in general have not proved remunerative below a depth of a few hundred feet. The General Custer vein is a feature of especial interest, and within the knowledge of the writer is unique in that erosion had exposed most of its ore body.

THE VEINS.

Distribution.—The veins of the district may be considered as two parallel systems about 4 miles apart. In each system four or five veins are recognized, most of which strike in a general northeast-southwest direction and dip westerly. The eastern system attains its maximum development on Custer Mountain, where it comprises the Badger, Lucky Boy, Enterprise, Summit, and General Custer veins. Southward it is represented on Dickens Hill by the Charles Dickens, Letha, and Julietta veins, and southwestward across Jordan Creek, by the Morrison, Fairplay, and Passover veins. The western system is best developed on Estes Mountain, where the Montana and McFadden veins are the most important representatives. Southwestward the deposits at Sunbeam should be considered in the same general group, although here much of the ore occurs as disseminations of irregular shape instead of in veins.

Characteristics.—The veins range from stringers to 18 feet or more in width, averaging perhaps 4 feet. In general their contact with the inclosing rock is sharp and the numerous included fragments are angular. Crustification is conspicuous throughout; the bands broadly parallel the walls, but in detail concentric arrangement is common. The predominant gangue mineral is cryptocrystalline quartz associated with which are small quantities of chalcedony, opal, and adularia. Calcite is important in some of the deposits, as in the Lucky Boy, where it comprises perhaps 20 per cent of the vein. The calcite occurs both as equidimensional rhombohedrons and as lamellar crystals, some of which have been replaced by quartz that retains perfectly the crystal form of the calcite.

Metallic minerals are irregularly distributed through the quartz and to a less extent through the calcite. In many places they are arranged as broken layers parallel to the banding of the gangue. Along the strike of the fissures the metallic minerals are largely confined to definite sections of the veins, thus forming the ore shoots, which have proved to be the only parts worth mining.

Ore shoots.—The ore bodies of the Yankee Fork district comprise (1) segments of otherwise comparatively barren quartz-calcite veins, (2) disseminations of stocklike form not related to fissure fillings, and (3) chimneys of ore apparently independent of fissure veins. The most important deposits belong to the first type, which is illustrated by all the deposits except the Golden Sunbeam and the Montana, the former being a great stocklike body and the latter a chimney of ore.

THE ORE.

The unaltered ore of the district is a fine-grained quartz, locally accompanied by considerable quantities of calcite and a little chalcedony, opal, and adularia. Scattered irregularly through the gangue,

yet conforming roughly to the crustification which characterizes it, are metallic sulphides, of which pyrite is most abundant and is present in all the deposits. In some of the veins, as the McFadden and Julietta, chalcopyrite and galena are also present, and in some of those about Custer enargite, probably also primary, was recognized. Tetrahedrite is not uncommon in the ores, although nowhere an abundant constituent. Most important, however, as they have been found to inclose the gold and silver, are blue-black submetallic bands and blotches which are present in all the better grades of ore. In these bands and blotches pyrite and gray copper and in a few specimens chalcopyrite are recognizable, but the predominant mineral occurs as minute blue-black specks too small to be identified. Partial chemical analyses of these bands show a definite trace of selenium, suggesting the presence of some selenide.

The oxidized ore is very different in appearance, being a firm quartz heavily stained with iron and manganese oxides and locally with malachite. Calcite appears in the immediate outcrop in but few places, but its former presence is indicated by lamellar and rhombohedral forms of quartz pseudomorphic after it. Kaolin of creamy white color, unless stained by iron, is common along crevices in the oxidized ore and is probably partly derived from the adularia of the gangue and partly infiltrated from the sericite and feldspar of the wall rock. The silver of the oxidized ore occurs as cerargyrite, argentite, and wire silver, and locally is found in conspicuous quantities. Gold is free but is generally so minutely divided that it is not visible to the unaided eye, although coarse gold has been reported from some of the deposits, notably the Morrison vein.

The ores of the district have been mined exclusively for gold and silver. In the western system of veins gold is commonly equal to or in excess of the silver, but in the eastern system silver greatly predominates. Extremes are possibly recorded in the General Custer vein, where there was 1 ounce of gold to 80 or 90 ounces of silver, and in the Montana shoot, where only traces of silver accompanied the gold.

ALTERATION OF WALL ROCK.

Metasomatic alteration of the wall rock is a conspicuous feature of the Yankee Fork gold-silver veins. It is impossible to take a specimen within 50 feet of the vein, and in many places within 1,000 feet or more, that is not intensely silicified or sericitized. The silicification is most intense next to the deposits and gradually dies out with increasing distance from them until at 100 feet or so secondary silica is scarce, if present at all. Well beyond this distance, however, sericitization is a conspicuous feature of the wall rock. This relation is well illustrated in the Golden Sunbeam mine. A specimen taken from the lower tunnel of this property at a distance of possibly 400 feet from the

main ore body is a chalky-white rhyolitic tuff, sparsely specked with iron stains. When microscopically examined it is seen to be made up of fragments of altered quartz and orthoclase scattered sparsely through a mass of highly sericitized material. A specimen taken from the similar rock next the ore body contains much secondary quartz, commonly as bunches of small anhedral crystals, accompanied by pyrite and a little sericite. The same relation exists in two specimens from the General Custer mine, one taken next the vein and the other 1,000 feet or so distant. The more remote specimen, however, is also chloritized. Similar pairs of specimens from the Lucky Boy and Charles Dickens properties show the same relation, seeming to indicate that in the deposits of the district as a whole the wall rock has been silicified near the veins and sericitized farther away.

AGE AND GENESIS.

The age of the Yankee Fork deposits is rather definitely limited by the age of the inclosing rocks on the one hand and the amount of preglacial erosion which has affected them on the other. Thus they are assigned to the late Miocene. (See pp. 49-50.)

Their genesis is less definite, but, as discussed on pages 49-50, several lines of evidence lead to the belief that they are genetically related to the igneous activity which earlier found expression in the great accumulation of tuffs and lavas that incloses them.

MINES AND PRINCIPAL PROSPECTS.

GENERAL CUSTER MINE.

Situation and history.—The General Custer mine is situated on the east wall of Yankee Fork Canyon near the town of Custer. The property comprises several claims located along the vein from a point near the valley flat at an elevation of 6,600 feet up the rugged mountain slope to an altitude of 8,500 feet. The vein was discovered in the late seventies and was worked actively most of the time from then until 1905, when it was closed.

The total production of the mine is said to be about \$8,000,000, most of which was extracted by a mill situated at Custer and connected with the workings by aerial tram. Prior to the construction of the mill, however, a considerable amount of ore was hand picked and shipped to Salt Lake, the returns averaging about \$600 per ton. The local mill is equipped with 30 stamps, several Wilfley tables, a roaster, and cyanide tanks.

Geologic relations.—The wall rock of the General Custer vein is a bluish-gray lava, probably andesite, which is now intensely altered. The phenocrysts of feldspar are completely changed to quartz, sericite, and calcite, and those of ferromagnesian minerals to quartz, sericite, and chlorite. A little sericite also appears in the groundmass,

which is studded with small grains of quartz and a few cubes of pyrite, both apparently secondary. This rock inclosed the upper 500 feet of the vein, now exposed, but below that portion a formation of different composition is said to have been encountered. The latter is probably one of the tuffaceous beds common in the district. A specimen secured at 7,300 feet from the next gulch north of the one occupied by the General Custer vein, and which is probably from the same bed of tuff, is a greenish-gray rock composed of fragments of unstriated feldspar in part altered to calcite and sericite. The ferromagnesian constituents are altered to chlorite and commonly arranged in beautiful spherulitic patches. This rock is probably a trachytic tuff. Beneath it andesite crops out again, as shown in the valley walls near Custer.

The vein.—The General Custer vein is a fissure filling which strikes N. 60° W. and dips 35° NE. It varies in width from a few inches up to 12 feet and in a few places to 18 feet, averaging perhaps 6 feet. The topographic relations of the vein are unique in that erosion has completely stripped the hanging wall from perhaps 80 per cent of its known extent, so that the ore lay as a great slab against the side of a narrow gulch tributary to the main canyon at Custer. Now that the vein has been worked off, the footwall resembles a dip slope pitching toward the bottom of the gulch and clearly records the structural disturbances which affected the vein after its formation. The wall is remarkably smooth and regular but is offset by several faults both along the strike and along the dip. The former throw the west side 5 feet to 20 feet to the south and the latter present drops of equal extent on the lower side.

Drifts to the east from the margin of the exposed portion showed that the vein split into two parts, neither of which was sufficiently metalized to constitute an ore; westward the vein has been removed by the erosion of Yankee Fork. Down the pitch of the ore shoot, which corresponded closely with the grade of the gulch, the ore changed on entering the tuffaceous beds, widening to 30 feet and becoming too low grade for profitable extraction.

East of the General Custer vein, on the same property, is a vein which crops out on the Summit claim at an elevation of 8,500 feet. It strikes N. 45° W. and dips 80° SE., thus according in general course with the other vein. The opinion held by some who are acquainted with the deposits that the lower vein is a portion of the upper which has "broken over," is not supported by geologic evidence; both are clearly in place.

The ore.—That portion of the vein which constitutes an ore is characterized by dark-colored blotches and bands which grade into the general gangue. The metallic minerals which give the dark color to these portions are in most places too minute for identification, but

locally gray copper, pyrite, and in a few specimens chalcopyrite can be identified in them.¹ The ore in that part of the shoot which has been developed is highly oxidized, and in many places is minutely fractured. Of the oxidation products which have formed, iron oxide alone is conspicuous, but manganese oxide and malachite occur locally.

The ore removed was of excellent grade, several of the earlier mill runs averaging from \$150 to \$300 to the ton in silver and gold. During the later stages of mining, however, the tenor fell to \$30 and lower. The gold was largely free, and the silver occurred as wire silver, argentite, and cerargyrite. The proportion of the metals was 1 ounce of gold to 80 or 90 ounces of silver.

LUCKY BOY MINE.

The Lucky Boy property, said to have produced about \$1,750,000, comprises several claims, two of which are patented. It is situated east-southeast of the General Custer group, at an elevation of 8,400 feet above sea level. The deposit was discovered about 1878, but not until the General Custer ore body began to show signs of exhaustion in the late nineties was it extensively opened. It was worked actively from then until 1904, the ore being carried by aerial tram to the General Custer mill. Development consists of two incline shafts, one of which attains a vertical depth of 900 feet, with drifts at 100-foot intervals.

The rock inclosing the Lucky Boy vein is a bluish-gray lava, probably andesite, which has been so completely altered in proximity to the vein that its identification is uncertain. Within this rock sericite is extensively developed, both in the groundmass and after the feldspar phenocrysts. Chlorite is present in small scattered patches and quartz is abundant as small grains and veinlets. Small cubes of pyrite stud the altered rock in many places, numbers of them being inclosed in the quartz veinlets.

The Lucky Boy deposit is a quartz-calcite vein which averages about 5 feet in width, though in places it narrows to a stringer and elsewhere widens to 15 or 18 feet. It strikes N. 85° E. and dips 64° NW. At the time of the investigation most of the workings were inaccessible, but from material on the dump it appears that the deposit contains 15 or 20 per cent calcite, much more than is present in any other known vein in the district. The calcite occurs both as lamellar crystals and as irregular areas; in many places it has been partially replaced by quartz. The predominant gangue mineral is cryptocrystalline quartz, which is generally arranged in bands parallel to the vein walls. Included in the gangue are numerous angular

¹ For other minerals, which a more thorough study would probably reveal in this ore, see the general discussion, p. 47.

fragments of wall rock which are intensely silicified and studded thickly with minute cubes of pyrite. Chalcedony and opal both appear locally in this deposit, but adularia was not recognized.

The precious metals accompany the darker bands of quartz. These bands owe their color to very minute metallic particles, which, though rather abundant, it was not possible to identify. Associated with them are small cubes of pyrite and a little gray copper. The ore is said to have contained gold and silver in about the same proportions as that of the General Custer, but was of lower grade.

BADGER MINE.

The Badger claim adjoins the Lucky Boy property on the east. The mine was worked intermittently for several seasons, the ore being treated at the General Custer mill, but for the past 12 years the property has been idle. The vein parallels the Lucky Boy, with which it corresponds in general characteristics.

BLACK MINE.

This property joins the Badger on the south, but has not produced as much ore. A 20-stamp mill situated on the property was operated intermittently for two or three years.

ENTERPRISE GROUP.

The Enterprise group comprises six unpatented claims situated a few hundred yards northeast of the Lucky Boy mine. Development consists of a tunnel 850 feet long and a few open cuts. Three ledges have been recognized on this property, two of which are possibly offshoots from the southern or largest ledge, which is known as the "back vein." This vein strikes N. 75° E. and dips 65° NW. It consists of a brecciated zone 25 or 30 feet wide which has been impregnated and cemented by vein quartz, in amount constituting perhaps one-half of the whole. Metallization is most intense near the hanging wall, where a cross section of 10 feet gave returns of \$10 to the ton in gold, together with traces of silver. The gold is probably contained in the ill-defined blue-black bands which traverse the quartz. In these bands pyrite is the only recognizable mineral, and it is not abundant. Laterally or vertically the lode has not been explored more than a few feet from the tunnel.

CHARLES DICKENS MINE.

The Charles Dickens mine is situated at an elevation of 7,200 feet on the south slope of Dickens Hill, a bold topographic feature bounded on the east by Yankee Fork and on the south by Jordan Creek. The property produced about \$600,000 in gold and silver bullion during the period from 1888 or 1889 to 1902. Development consists principally of a tunnel and a winze from it, the total depth attained being about 250 feet.

The vein, which strikes N. 70° E. and dips 70° to 75° NW., is a fissure filling ranging in width from 2 to 6 feet. It is inclosed in tuff in its upper portion and probably in andesite in the lower workings. The gangue is the fine-grained quartz common in the deposits of the district. Associated with it, however, there seems to be less calcite and more of the base metals than is common elsewhere. Small cubes of galena, irregular specks and bunches of chalcopyrite, and small areas of gray copper are common in the better grades of the primary ore. Gold is not visible. In the oxidized ore the valuable minerals are free gold, wire silver, cerargyrite, and argentite.

MORRISON GROUP.

The Morrison property is situated across Jordan Creek west-southwest from the Charles Dickens. The property produced about \$100,000 during the early days of the camp. It was not visited during the reconnaissance but is thought to be a continuation of the Charles Dickens, with which it corresponds in strike and dip.

FAIRPLAY, PASSEOVER, LETHA, AND JULIETTA CLAIMS.

South of the Morrison mine are the Fairplay and Passover claims, each of which has produced \$20,000 to \$25,000. North of these, across Jordan Creek, are the Julietta and Letha claims; the former has produced a few thousand dollars and the latter \$60,000.

GOLDEN SUNBEAM MINE.

Situation and history.—The Golden Sunbeam group, comprising nine claims and three fractional claims, is situated on the south side of Jordan Creek, 4 miles above its confluence with Yankee Fork. The property was worked for several years prior to 1906, but not until then was extensive development begun. About this time a large irregular body of ore was encountered, which encouraged the operators to construct a 450-ton mill and install a hydroelectric plant on Salmon River, 10 miles distant. The mill is arranged for six Monadnock mills, four of which are installed. Two of the mills were operated for a time with indifferent success, and in June, 1911, the plant was closed. It is said that on broad averages the deposit was of too low grade to be worked at a profit. The property is said, however, to have produced about \$400,000 from gold and silver.

Development consists of three tunnels and two intermediate levels in the main mine, the Bismarck tunnel a short distance south of it, and the Matilda to the north, in all perhaps 8,000 feet of tunnel work. The maximum depth on the deposit is 440 feet.

Character of the deposit.—The Golden Sunbeam ore bodies comprise mineralized zones and chimneys of ore in bedded tuffs. Locally, as in the Bismarck tunnel, the ore follows fairly well defined brecciated zones and thus resembles the veins found elsewhere in the district, but in general there is little evidence of fissure filling. The most

important ore body, locally known as the "big stope," was an irregular mass which on No. 2 level was 130 feet long by 75 feet wide. From this level it extended upward 85 feet and downward 115 feet. Most of the production came from this stope, the ore running \$2 to \$4 to the ton. The shoot had a general strike N. 30° E. and stood nearly vertical.

The ore, as seen on the margin of the "big stope," is a soft grayish-yellow rhyolitic tuff studded sparsely with small specks of iron oxide, doubtless due to the alteration of pyrite crystals. In a few places copper stains also are present. The tuff is intensely silicified near this stope, minute bunches and scattered grains of secondary quartz being abundant. A specimen taken about 200 feet from the same stope is not silicified but is extensively sericitized.

Both in the "big stope" and elsewhere on the property vertical fractures are followed by narrow stringers of ore, in places high in grade. These stringers, however, are so small that as a rule it has not paid to mine them. The gold is pale yellow, owing to the high percentage of silver, in some specimens more than one-half, which is associated with it. Near the surface native silver is said to have been found, and with it a purer grade of gold, which suggests a separation of the two metals during oxidation.

MONTANA MINE.

The Montana mine is situated on the south slope of Estes Mountain, a few hundred feet below its summit. The property was worked many years ago and was reopened in 1905 to 1907. It has produced \$337,000, most of which was recovered from a shoot 20 to 25 feet in length by 5 to 17 feet in width, which extended to a depth of 530 feet. In the upper 250 feet the shoot dipped 80° W., flattening below to 45°. The inclosing rock is a fine-grained tuff rather intensely silicified near the ore shoot. The ore differed from that found elsewhere in the district in the small quantity of silver associated with the gold, less than 1 ounce to the ton being common.

McFADDEN GROUP.

The McFadden group of two patented claims lies on the northeast slope of Estes Mountain at an elevation of 8,600 feet. The property was located in 1878 and has been worked at intervals since, producing in all about \$200,000. Development consists of about 2,000 feet of tunnels and a shaft 500 feet deep. A 10-stamp mill is situated on Eightmile Creek, 3 miles below the mine.

The vein, which strikes N. 20° E. and dips 37° NW., lies between a hanging wall of light-gray fine-grained tuff and a footwall of greenish-gray porphyritic rock, possibly andesite. Both are intensely silicified, and in the footwall rock zoisite and chlorite are also abundantly

developed. The vein averages about 3 feet in width and is composed principally of coarse quartz roughly crustified parallel to the walls or concentrically banded about included fragments of wall rock. Both intergrown with the quartz and included in it are a few crystals of adularia. The metallic minerals are distributed erratically through the quartz and consist chiefly of chalcopyrite, pyrite, tetrahedrite, and galena, decreasingly abundant in the order named. The gold and silver are associated with these minerals in the ratio to each other of about 1 to 100. The ore occurs in two shoots which are poorly defined but range in length up to possibly 100 feet. In the upper workings oxidation is well advanced, but about 200 feet below primary minerals predominate. The oxidized ore is stained with iron and copper and contains seams and small isolated specks of kaolin, the last probably derived from the alteration of adularia.

GOLDEN GATE GROUP.

The Golden Gate group joins the McFadden on the north. The two mines are on the same vein and as the geology is similar in both it will not be necessary to repeat the description. One ore shoot is recognized in the 1,000-foot tunnel which comprises the development on this property. From it some ore has been taken, but the production is much less than from the McFadden mine.

OTHER PROPERTIES ON ESTES MOUNTAIN.

Several other veins are recognized on Estes Mountain, but they are little developed and have produced only small amounts of bullion.

YANKEE FORK PLACERS.

Placers, said to have produced \$50,000 in gold, were discovered in the middle seventies on Jordan Creek, near its junction with Yankee Fork. About the same time gold was found in the high bars below Bonanza, but these have never proved profitable. During the past few years the valley flat along Yankee Fork from Salmon River to Jordan Creek and thence along that stream for about 2 miles has been located, and extensive exploration carried on by drilling, but with what success is not known to the writer.

The gravels form broad terraces, said to be 90 feet deep in places although averaging possibly less than 30 feet. Little is popularly known of the distribution of gold in the gravels except on Jordan Creek, where the placers have been largely worked out. Here the gold was next to bedrock, and although commonly fine some large nuggets were obtained, one weighing 32 ounces being said to have been found near the outcrop of the Morrison vein. Several others from the same vicinity weighed 8 or 10 ounces, and many exceeded 1 ounce in weight.

LOON CREEK DISTRICT.**SITUATION.**

The Loon Creek mining district comprises an unorganized area of perhaps 75 square miles situated in the northwestern part of Custer County. It lies immediately west of Sheep Mountain district and about 15 miles northwest of Yankee Fork district. Mackay, 110 miles southeast of Ivers, the principal local settlement, is the most accessible supply point. To reach Ivers from Mackay, however, it is necessary to cross two high summits in addition to a 3-mile climb from the mouth of Canyon Creek to the settlement. The roads are better than in most mountainous regions, but owing to snow on the summits are impassable for teams during the winter months.

MINING CONDITIONS.

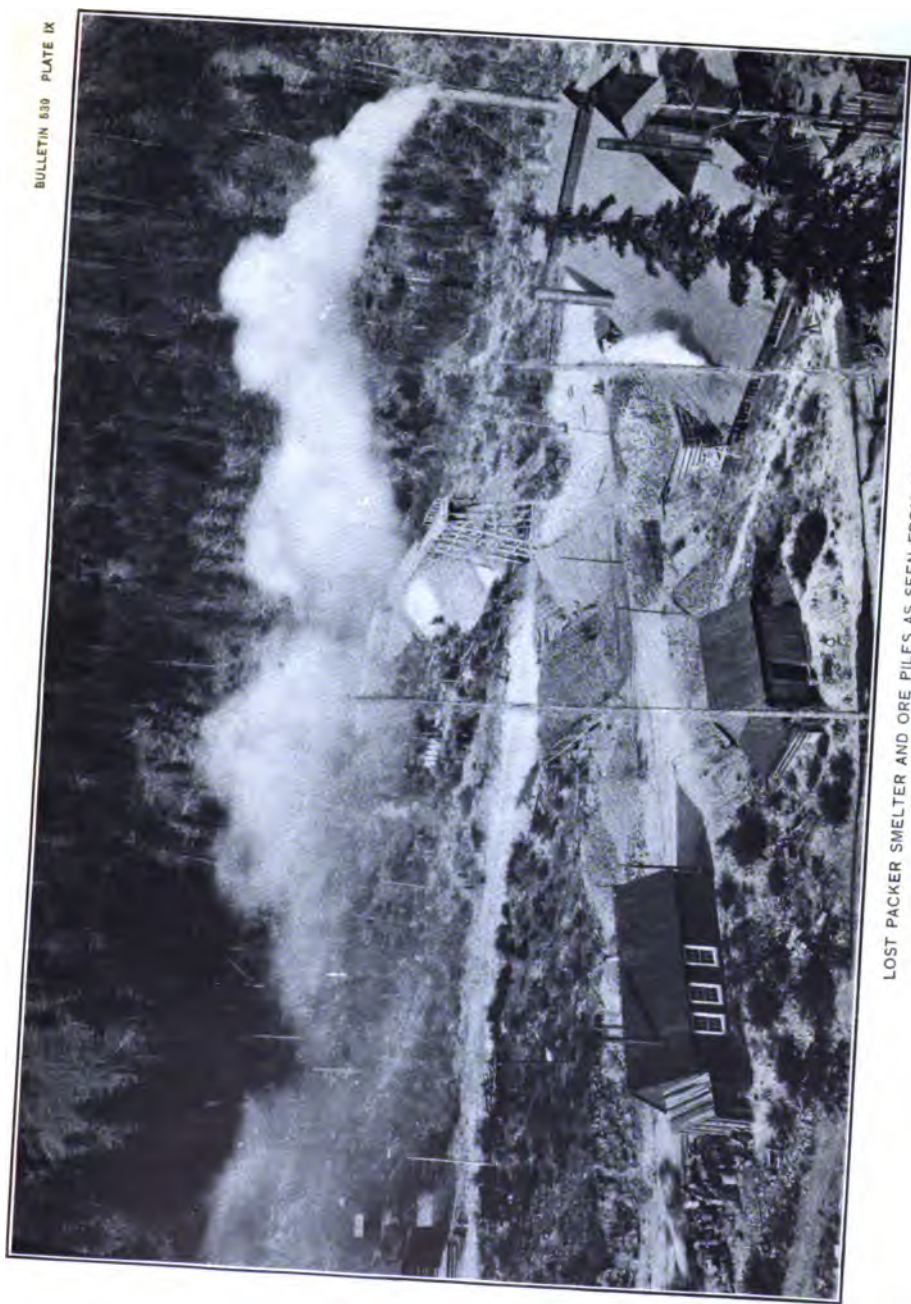
The Loon Creek district is a well-timbered and well-watered region of bold topographic forms. Owing to the range in elevation from 5,000 to 9,500 feet, the district experiences a great variety of climatic conditions. Snow covers the higher areas to a depth of several feet throughout the winter months, but in the lowlands the weather is seldom severe.

The area is well adapted to mining operations. The abrupt transitions from lowlands to highlands make it feasible to explore most of the known deposits to a depth of 1,000 to 2,000 feet by means of tunnels. Local smelting is facilitated by an abundance of suitable fluxes within the area. Indeed the only handicap to successful and economical mining is the expense of freighting supplies, especially coke, from the Oregon Short Line terminus at Mackay, 110 miles distant. The cost of this haulage is 2½ cents a pound for the round trip. When loaded both ways this is spilt into 1½ cents in and 1 cent out. The cost of coke, therefore, is the prime problem in local smelting, its average price laid down at Ivers being \$46 per ton.

The various expenses charged against a ton of ore delivered as matte free on board at Mackay aggregate \$20 to \$22. It is this high cost which retards mining activity in the Loon Creek and adjoining districts; the need of the region is railroad transportation. Only ore running \$70 to \$90 a ton has been smelted, but for every ton of this grade which has been developed there are estimated to be 2½ tons which will average \$25.

HISTORY AND PRODUCTION.

Placers which produced a large amount of gold were worked actively on Loon Creek during the decade closing with 1879. Most of the production, however, dates from the first half of this period, the excitement gradually dying out until only 30 or 40 Chinese



LOST PACKER SMELTER AND ORE PILES AS SEEN FROM THE SOUTH.

remained, who were massacred in the winter of 1879 by a band of men supposed at that time to be Indians but now commonly believed to have been whites. Since that time comparatively little mining has been done on the creek, although all the promising ground is now held as placer claims.

The principal lode mine in the district at present is the Lost Packer, located by Clarence E. Eddie in July, 1902. Soon thereafter it was purchased by Ivers & Finlan, of Salt Lake, who instituted development in the spring of 1904. A 100-ton smelter (Pl. IX) was completed in 1905, and although it has been necessary to haul coke 110 miles consistent development has been carried on with the returns from three short smelter runs—one in 1907, one in 1908, and another in 1911.

Numerous other properties have been located in the district, but they are little developed and most of them have changed hands several times, successive holders becoming discouraged because of the difficulties of transportation.

The total production of Loon Creek district is variously estimated from \$1,000,000 to \$2,500,000, \$500,000 of which is credited to the Lost Packer lode and the remainder to the gold placers during the decade of their activity which closed with 1879. In recent years the placers have produced a small amount, the recovery each year being sufficient to pay assessment costs. The lode production includes both gold and copper, about \$150,000 having been derived from the latter. A good grade of lead-silver ore occurs in the district, but little or none has been marketed.

GEOLOGY.

Physiography.—The Loon Creek district is a high mountainous region ranging in elevation from 5,000 to more than 9,500 feet. Loon Creek, a rapid stream, averaging perhaps 30 feet in width, flows north through the area. Its more important tributaries are Mayfield and Cottonwood creeks from the east and Trail Canyon and Grouse creeks from the west. The area is a part of the broad region known as the Salmon River Mountains and preserves on its highest parts the Eocene erosion surface from which those mountains were carved. This feature constitutes the most valuable geologic datum plane in the area. The topography and geology of a part of the district are shown on Plate X.

Sedimentary rocks.—The oldest rocks in the area are mica schists and quartzites of Algonkian age. They outcrop over an irregular area of about 2 square miles in the central part of the district. In most directions they are cut off by quartz diorite which invaded the region in late Cretaceous or early Eocene time, but northward they disappear beneath a capping of quartz latite. These ancient

sediments are intensely metamorphosed, a strong schistosity, which strikes west of north and dips southwest, obliterating the bedding structure in most exposures.

Beds of Paleozoic age overlie the Algonkian deposits and are separated from them by a marked structural unconformity. These beds are confined to the south-central portion of the district. They are steeply inclined to the east, south, or southeast, the direction varying from place to place. Within them schistosity occurs only along special zones of shearing; thus they are readily distinguishable from the underlying Algonkian, from which they differ also in composition.

The Paleozoic beds consist of fine-grained quartzites and massive blue dolomitic limestones, neither of which yielded fossils on a cursory examination. Nevertheless the lithologic similarity of the beds to those at Gilmore, Lemhi County, suggests that the quartzite is of Cambrian age and that the massive blue dolomitic limestone is Ordovician. This assignment is apparently refuted by the juxtaposition of the Algonkian schist with the dolomitic limestone near Lost Eagle mine, but it is thought that this contact records faulting, although, owing to a thick mantle of soil, the relation was not determined with certainty. The thicknesses of the quartzite and dolomite were not determined. Higher horizons of the Paleozoic probably outcrop in the extreme south-central part of the district, but this area was not visited.

Igneous rocks.—Igneous rocks of diversified types and widely different ages are present in the district. The oldest and most important of these rocks is a great batholith of quartz diorite which extends into the area from the west and again crops out along its eastern border. It is a dark-gray rock, composed of oligoclase, quartz, conspicuous amounts of biotite, and subordinate hornblende. Orthoclase, titanite, and apatite are accessory. This batholith is thought to be a phase of the great granitic magma which invaded central Idaho in late Cretaceous or early Eocene time and which now crops out over a continuous area more than 20,000 square miles in extent.

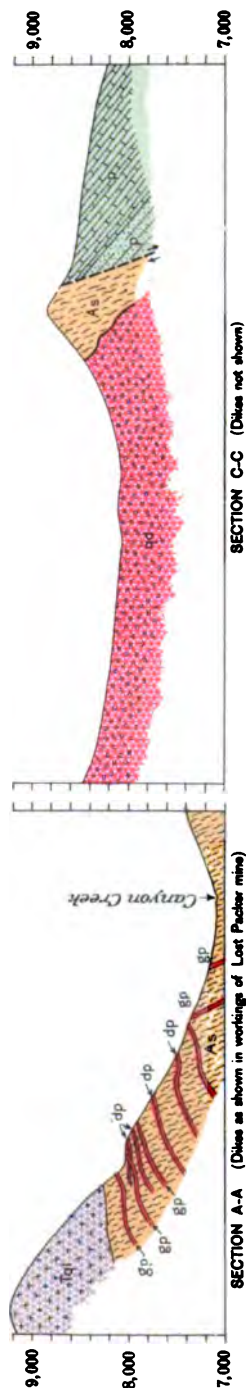
Soon after the quartz diorite invasion came the intrusion of numerous medium-grained granite dikes, peculiar because of their small content of ferromagnesian minerals. These dikes are from 2 or 3 to more than 30 feet in width; yet the texture in all is about the same. In general they follow the schistosity of the Algonkian rocks, but locally they cut across it.

Subsequent to the intrusion of the granite dikes there entered dikes and sills of granite porphyry and diorite porphyry. These dikes are excellently exposed in the Lost Packer mine, where they traverse the ore body in several places (fig. 4, p. 95). On No. 3 level they intersect, but in this place the fine grain and extremely altered



SECTION B-B (Dikes not shown)

Elevation in feet

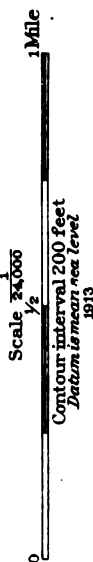


SECTION A-A (Dikes as shown in workings of Loon Picher mine)

SECTION C-C (Dikes not shown)

TOPOGRAPHIC AND GEOLOGIC MAP AND SECTIONS OF A PORTION OF THE LOON CREEK DISTRICT, IDAHO

By Joseph B. Umpleby





condition of the specimens collected from the older dike make it impossible to classify it definitely. The younger dike also is altered, but numerous quartz phenocrysts indicate that it is a granite porphyry. Near the portal of No. 6 tunnel the diorite porphyry presents a marginal facies similar in appearance to the older dike in No. 3 tunnel, and this is thought to further indicate that the granite porphyry is the younger intrusion. In the larger dikes a phenocrystic development of quartz characterizes the granite porphyry, but this is lacking in the narrower dikes. The age of these intrusions is not definitely known, although they are thought to antedate the Eocene erosion surface.

Quartz latite flows, still younger than the granite and diorite porphyries, cap the summit above the Lost Packer mine. They rest on an uneven erosion surface of post-Eocene age, but further than this the period of their extravasation is not fixed. They are gray in color and made up of phenocrysts of oligoclase, quartz, and biotite set in a fine-grained groundmass, which constitutes over one-half of the rock and which from partial chemical analysis is known to contain considerable potash. (See p. 26.)

Glacial deposits.—During the Pleistocene epoch glacial ice covered those parts of the area above 8,000 or 8,500 feet and sent tongues down the larger valleys to points about 7,000 feet above the sea, locally perhaps to 6,500 or even 6,000 feet. Evidence of such glaciation is presented by all the larger valleys. At their heads are invariably steep-sided cirques, many of them occupied by small lakes. Below these cirques the canyons are broad and U-shaped for a distance, with morainic material along their sides and bottom, but finally they become narrow and V-shaped. This transition in most places marks the lower limit of glaciation.

ORE DEPOSITS.

GENERAL CHARACTER.

The Loon Creek district comprises an area noteworthy at present because of its gold deposits, including lodes in which chalcopyrite, quartz, and siderite carry the gold, and placers along the streams in favorable places below them. In addition to the gold-bearing lodes, lead-silver deposits are found in the district. These lead-silver deposits have been inadequately prospected, but the ore is of excellent grade, being in many places clean galena that carries from 60 to 100 ounces of silver to the ton.

Iron and lime fluxes are abundant along the contact between the Paleozoic dolomitic limestone and the quartz diorite south of Ivers. They are especially valuable as they contain about 60 cents in gold and 1 ounce in silver to the ton—almost sufficient to pay for handling them.

GOLD PLACER DEPOSITS.

The Loon Creek Hydraulic Placer Co. owns six claims, in all 470 acres, which extend from a point near the mouth of Canyon Creek to the Loon Creek Narrows, $4\frac{1}{2}$ miles north. Their average width is approximately 1,000 feet. A strip about 75 feet wide and 1 mile long, comprising the upper part of the central channel, was worked during the sixties and is variously estimated to have produced from \$500,000 to \$2,000,000, an occasional pan having yielded as much as \$300. These gravels were 2 to 6 feet thick, but back of them are gravel terraces which were not explored during the early days. The present owners prospected these terraces during two seasons and obtained an average yield of 25 cents a cubic yard. A flume capable of delivering 80 second-feet of water to any part of the ground is partly completed, and will probably be in operation in a short time. Heretofore water has been derived from two small streams—Grouse Creek and White Creek—but the present plans include the diversion of Loon Creek at a point well above the placer grounds.

The auriferous gravels rest on a floor of schist, which as now exposed presents a comparatively even surface. The inclosing gravels are usually less than 6 inches in diameter, although in places at various distances from the base of the deposits boulders as much as 3 feet and a few up to 6 feet in diameter are encountered. As the gravels are loosely cemented they fall apart readily when undermined by the hydraulic giant. The beds are in few places more than 15 or 20 feet thick, although locally they attain a depth of 30 to 40 feet. The gold is near bedrock and in joints and shallow depressions in it. As a rule the gold is coarse, nuggets weighing more than an ounce being not uncommon, and perhaps 50 per cent of the product averages 25 cents or more to the color. The market value is \$18 an ounce.

GOLD-COPPER DEPOSITS.**THE LOST PACKER VEIN.**

Situation and development.—The Lost Packer vein, the principal lode deposit in the Loon Creek district, crops out here and there along a course extending north from the town of Ivers. It follows roughly a steep, narrow gulch, which within 4,000 feet attains an elevation 2,000 feet greater than that at Ivers. The development comprises eight tunnels which enter along the strike of the vein, the lowest, or No. 10, attaining a depth of 1,000 feet below the quartz latite flow that caps the vein at an elevation of 8,700 feet. The levels are numbered from No. 1, driven 100 feet below the apex of the vein, to No. 10, the lowest, and all except Nos. 5 and 9 connect directly with the surface. (See fig. 4.)

General character of the vein.—The fissure followed by the Lost Packer vein strikes N. 5° E. and dips 75° NW. It has been traced from

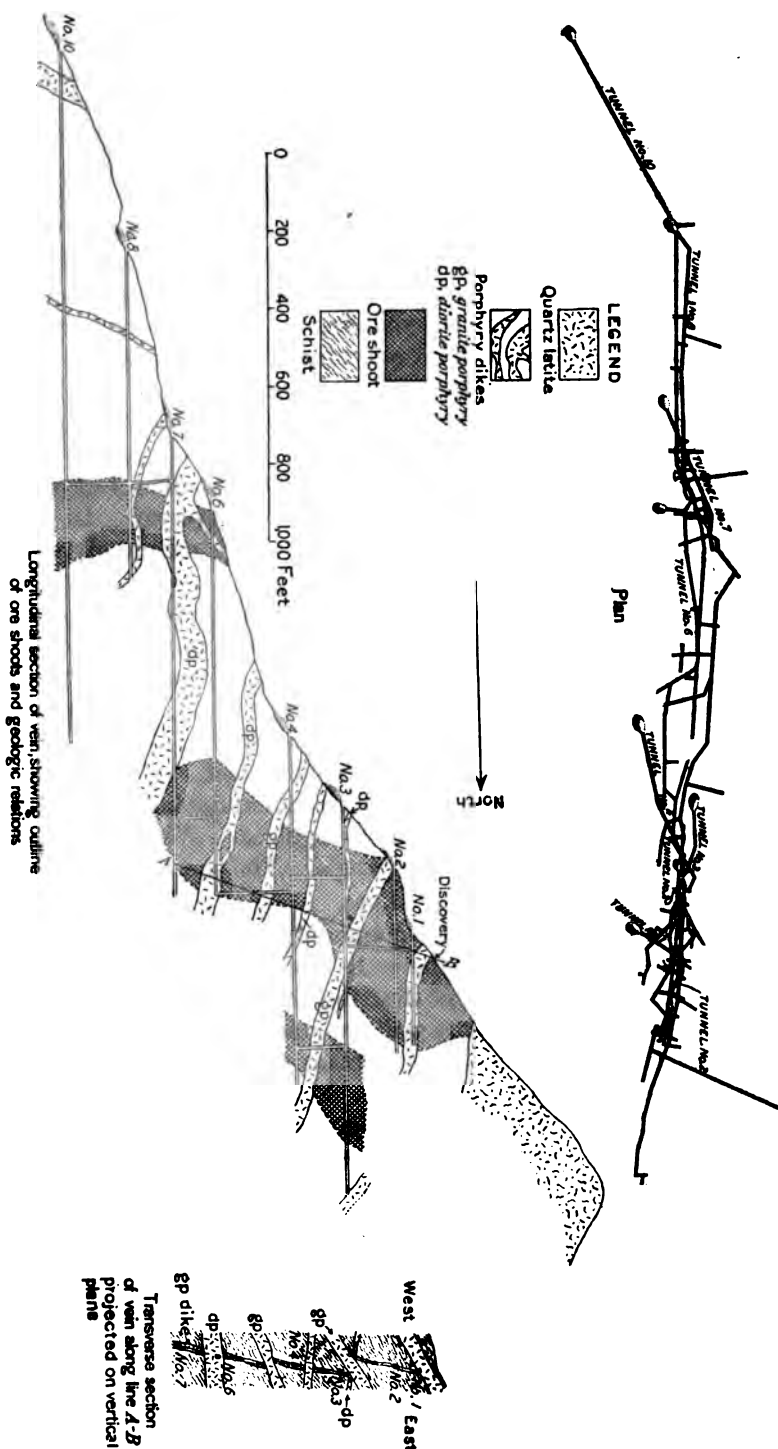


FIGURE 4.—Plan and sections of Loon Packer mine, Loon Creek district, showing the geology.

Canyon Creek, at Ivers, north about 3,000 feet to the dacite cap above the mine. South of Canyon Creek it has not been definitely recognized, although a few small prospects have been opened on its general course. Northward, where the fissure has been explored by tunnels throughout about 2,000 feet of its extent, it presents well-defined walls, which commonly stand 3 to 5 feet apart, with gouge, sheeted wall rock, and ore between them. The walls present numerous slickensides, but distinct grooves having even an approximately uniform direction were not noted. Within the gouge also there is abundant evidence of shearing and gliding of contiguous parts, all bespeaking important movements along the vein fissure. Most of the movement, however, antedates the ore and determined the channels along which the ore-bearing solutions entered. Evidence of extensive displacement along this plane is apparently lacking; the dislocation probably did not exceed a few score of feet at most.

The fissure traverses the schists and granite dikes but is itself crossed by the granite porphyry and diorite porphyry. In general it cuts the structure planes of the schists, which commonly strike a little west of north at a low angle.

The vein material follows the fissure closely, although in a few places as far as 20 feet from it small lenses of chalcopyrite occur in the schist. Within the fissure the ore is distinct from the gouge and sheeted schist and usually comprises a single band, either next the hanging wall or footwall, more often next to the latter. The ore varies in width from a narrow stringer to 4 or 5 feet, averaging perhaps 20 inches. Along the strike of the fissure mineralization is so localized that three distinct shoots of ore are recognized. Where not vertical each shoot pitches south at a high angle. The shoots are connected on most levels by narrow bands of ore.

Even though ore and gouge are commonly present in the same cross section, it seems that where the walls are farthest apart the ore is widest. This relation suggests that the shoots are determined by a relative movement of the fissure walls sufficient to bring reverse curves opposite each other; a suggestion further supported by the parallel arrangement of the shoots.

The ore.—The ore consists of auriferous chalcopyrite in a siderite-quartz gangue, the relative importance of the three minerals varying markedly from place to place in the same shoot and especially in the different shoots. Thus in the south shoot siderite predominates and in the two others quartz is most important. The relative amount of chalcopyrite is greatest in the middle shoot, where it represents about one-third of the total vein material. The Lost Packer ores are exceptional in the amount of gold associated with the chalcopyrite; assays of this mineral usually show $2\frac{1}{2}$ to 3 ounces of gold to the ton. Equally important with the chalcopyrite as a carrier of gold is the

quartz, especially that of the middle shoot, but the siderite as a rule does not contain more than half an ounce of gold to the ton. In both the chalcopyrite and the quartz silver runs about $2\frac{1}{2}$ ounces to the ounce of gold. The total production of the property, about one-half million dollars, has been derived from ore averaging between \$80 and \$90 to the ton. However, for every ton of this grade which has been encountered in the mine there is estimated to be $2\frac{1}{2}$ tons which average \$25.

Mineralogically the ore is comparatively simple; chalcopyrite, siderite, and quartz only are common. A little calcite is present. Pyrite is exceedingly rare, occurring as small grains and cubes, usually included in the chalcopyrite. Pyrrhotite has a similar distribution but is even less abundant. Jennings¹ reports barite as a primary constituent, but careful search during the present studies failed to reveal this mineral. The oxidation products are principally iron oxides and the carbonates of copper. Immediately beneath the surface films of bornite and native copper are locally present, but here also the chief alteration products are malachite, a little azurite, and much limonite and hematite.

Ore shoots.—The three ore shoots recognized in the Lost Packer vein present important differences in constitution and form and hence will be discussed separately. Each stands vertical or pitches south at a high angle.

The north shoot is reached only by No. 4 and No. 3 tunnels. On the former level it is 120 and on the latter 250 feet in length, the average width on each being about 2 feet. The ore consists of coarse-textured milky to bluish-white quartz with chalcopyrite and a little pyrite irregularly scattered through it, the chalcopyrite frequently inclosing small cubes and grains of the pyrite. On No. 3 level siderite is rare, but on the next level below it is equally abundant with chalcopyrite and has a similarly irregular distribution. This ore body is comparatively lean, roughly sorted material running about \$20 to the ton—one-half ounce of gold, 2 ounces of silver, and $3\frac{1}{2}$ per cent of copper.

The middle shoot is by far the most important in the mine. It lies 200 feet south of the north shoot and is developed from the seventh level to the quartz latite cap 700 feet above. The southern limit of the ore is a fairly regular line, but the north boundary is not parallel to it. Thus the shoot is about 500 feet long on No. 2 level, narrowing both above and below, its average length being about 300 feet. Locally the shoot appears at the surface as a honeycombed quartz heavily stained by iron together with a little manganese oxide and copper carbonate, but in most places it has little or no surface expression.

¹ Jennings, E. P., The Lost Packer copper-gold lode [Idaho]: Jour. Canadian Min. Inst., vol. 9, 1906, p. 56.
98185°—Bull. 539—13—7

The ore ranges in width from a few inches to 4 or 5 feet, averaging about 20 inches, and wedges out on the ends of the shoot. This wedging out of the shoot seems to bear a definite relation to the tenor of the ore, for it has been commonly found that as the ore body narrows its assay value diminishes. Thus the ends of stopes temporarily abandoned are generally in ore running about \$25 to the ton, whereas the portion removed averaged between \$70 and \$90 to the ton. On No. 4 level the shoot is shorter than elsewhere in the mine and here also it contains a minimum amount of gold to the ton. Ore from levels both above and below contained 2 to 3 ounces to the ton, but here less than 1 ounce was present.

The ore consists essentially of chalcopyrite distributed as bunches, small patches, irregular grains, and interstitial fillings in a gangue of coarse white quartz. The chalcopyrite constitutes about one-third of the total material mined. Siderite is present in small quantities, but is nowhere an important constituent. The chalcopyrite and quartz each carries about 3 ounces in gold to the ton, but less than half an ounce is present in the siderite.

The south shoot of ore differs markedly from the other two in its high content of siderite. It lies 500 feet south of the middle shoot, and is developed from No. 10 level to its outcrop near the portal of No. 6 tunnel. This ore body ranges in length from 75 to 150 feet and is about 20 inches wide. It consists of siderite and chalcopyrite intergrown with coarsely crystallized quartz in such proportions that the ore runs 26 per cent of iron and $4\frac{1}{2}$ per cent of copper. Gold and silver averaging half an ounce and 3 ounces respectively are present. This ore body is a valuable asset to the mine because it combines a fair amount of the precious metals and copper with an excess of iron, an element which must be added in the smelting of ores from the other shoots.

Considerable ore was blocked out in the mine at the time of visit, and this was materially increased during the last year. Returns from the last smelter run were used to extend No. 7 tunnel beneath the north shoot and No. 10 tunnel beneath the middle shoot (fig. 4, p. 95).

UNDEVELOPED VEINS.

A description of the Lost Packer vein constitutes essentially a description of the known gold-copper deposits of the district. Other veins are recognized, but they are little developed and have produced only returns from test samples. Among these, the Effa ledge, which outcrops a few hundred feet west of the Lost Packer vein, is promising. The Sunset and South Packer groups also present some encouragement to the operators, although the small amount of development on them has not revealed commercial deposits.

SILVER-LEAD DEPOSITS.

Silver-lead deposits have been found near the dolomite area south of Ivers. The Lost Eagle claim and the Metcalf group are the principal properties, but neither is sufficiently developed to afford a satisfactory idea of the nature or extent of this ore body. Their occurrence, however, is thought to be of special significance, and therefore they will be described briefly. The Lost Eagle claim is situated on the divide between Canyon and Deer Creek cirques, at an elevation of 8,800 feet above sea. It is inclosed in Algonkian schist, though removed but a few hundred feet from an area of Paleozoic dolomitic limestones. Development consists of a shaft 50 feet deep and a short drift from it. The vein, which strikes N. 5° W. and dips 85° SW., is about 6 feet wide and bordered by well-defined walls. Between them is crushed wall rock with bands and interstitial areas of argentiferous galena, pyrite, and a little chalcopyrite in a quartz-siderite gangue. (See Pl. VIII, A, p. 44.)

The Metcalf property, situated about 1,000 feet northeast of the Lost Eagle shaft, contains an irregular vein partly developed for about 100 feet along its outcrop. The deposit is a fissure filling inclosed in granite near its contact with Paleozoic dolomitic limestone. The ore consists of argentiferous galena, which fills the fissure almost exclusively and ranges in width from a narrow stringer in most places to 3½ feet in other places. The galena contains about 1 ounce of silver to the unit of lead.

In each of the deposits just described the amount of ore actually found is not of so much significance as its geologic occurrence. Both deposits as now known are inclosed in rocks which are not nearly as favorable to the deposition of lead ore as is limestone, even when impure; hence, in the opinion of the writer, the area of dolomitic limestone adjacent to these deposits should be encouraging territory for the prospector. In the few places where time permitted an examination of the limestone area it was found to be rather intensely mineralized, as illustrated by the three iron mines which supply flux to the Ivers smelter, each of which is in a deposit of pyrite, now oxidized, which has replaced the dolomitic limestone.

AGE AND GENESIS.

The Loon Creek deposits crop out at elevations ranging from 7,200 to more than 9,000 feet; the greatest elevation is essentially that of the present Eocene erosion surface. As the mineralogy of the deposits clearly indicates deposition at great depth, a depth probably exceeding 3,000 or 4,000 feet for the Lost Packer vein, where pyrrhotite occurs, it is evident that the veins were formed before the close of the Eocene epoch. On the other hand, the

Metcalf deposit is inclosed in granite and the Lost Packer cuts across granite dikes; thus the deposits are postgranitic. If the granite caused or accompanied the elevation which resulted in the Eocene erosion surface, as brought out in another paper,¹ it follows that the age of these ore deposits is limited to the late Cretaceous or early Eocene.

The genesis of the deposits is not susceptible of as satisfactory analysis. From broad considerations discussed on page 45, it is concluded that these deposits are genetically related to the quartz diorite intrusion. Just what part that intrusion played, however, is not clear. It is certain that two distinct types of ores were deposited, namely, gold-copper ores and silver-lead ores. Both occupy fissures, but the former are in schist and the latter not far removed from thick beds of dolomitic limestone, thus suggesting the possibility that the beds traversed by the solutions exercised some control on the nature of the deposits. But to accept this view it seems necessary to suppose that the metals either were derived in large part from the stratified rocks or that the different rocks precipitated different metals from the same magmatic solutions. The latter view seems more tenable, as if the intrusion served only to stimulate meteoric circulation, ore deposits should occur in connection with the later intrusions also. It is thought, therefore, that the Loon Creek ore deposits owe their origin to solutions given off from the quartz diorite magma during the later stages of its consolidation.

A study of the sequence in which the minerals were formed brings out some interesting facts in the deposition of the ores. In both the gold-copper and the silver-lead deposits siderite was the earliest mineral to form, followed by chalcopyrite and quartz in the former, and galena and quartz in the latter. Chalcopyrite, galena, and quartz replace the siderite, as shown by their protuberances and the thin films of them which follow fractures and cleavage planes in the siderite. This seems to indicate that in their early stages the solutions were highly charged with carbon dioxide, and that later the copper and lead-bearing compounds, possibly chlorides of these metals plus hydrogen sulphide, became of paramount importance in the solutions.

¹ Umpleby, J. B., An old erosion surface in eastern Idaho; its age and value in time determinations: *Jour. Geology*, vol. 20, 1912, pp. 139-147.

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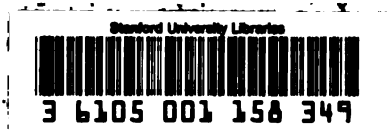
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